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**NASA TECHNICAL  
MEMORANDUM**

NASA TM X-64685

## Volume II of IV

# MANUFACTURE AND QUALITY CONTROL OF INTERCONNECTING WIRE HARNESSES

September 1, 1972

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# George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama

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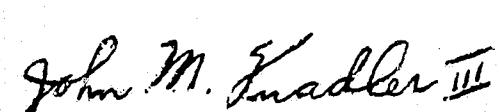
## 15. SUPPLEMENTARY NOTES

Prepared under the overall direction of the Quality and Reliability Assurance Laboratory

16. ABSTRACT This document has been prepared for use as a standard for manufacture, installation, and quality control of eight types of interconnecting wire harnesses. It is made up of four volumes under one reference number to simplify control and referral on contracts. Each volume can be independently employed should only harnesses within one volume be of interest. The processes, process controls, and inspection and test requirements reflected are based on (a) acknowledgment of harness design requirements defined in MSFC document 40M39582, "Harness, Electrical Design Standard," (b) acknowledgment of harness installation requirements defined in MSFC-SPEC-494, "General Specification for installation of Harness Assembly (Electrical Wiring), Space Vehicle," (c) identification of the various parts, materials, etc, utilized in harness manufacture, and (d) formulation of a typical manufacturing flow diagram for identification of each manufacturing and quality control process, operation, inspection, and test.

The document covers interconnecting wire harnesses defined in the design standard. Volume I covers type I, enclosed in fluorocarbon elastomer convolute, tubing; type II, enclosed in TFE convolute tubing lined with fiberglass braid; type III, enclosed in TFE convolute tubing; type V, combination of types III and IV: Volume II covers type IV, open bundle (not enclosed); Volume III covers type VI, enclosed in TFE heat shrink tubing; type VII, flexible armored; and Volume IV covers type VIII, flat conductor cable. Volume breadth covers installations of groups of harnesses in a major assembly and the associated post installation inspections and electrical tests. All vol's are TM X-64685.

Knowledge gained through experience on the Saturn V Program coupled with recent advances in techniques, materials, and processes have been incorporated into this document.

17. KEY WORDS Space Vehicle Wiring Interconnecting Wiring Harness Design Harness Fabrication Harness Inspection Harness Installation	18. DISTRIBUTION STATEMENT Unlimited - Unclassified   John M. Knadler, III, Technical Monitor Task 2026-TA-15		
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## PREFACE

Throughout the Saturn Program, refinements in interconnecting wire harness designs, manufacturing and installation techniques, and inspection and testing requirements were implemented to achieve optimum reliability in space vehicle and payload electrical systems. The preparation of this document was undertaken to assure such learning as was afforded by the Saturn Program is made available for future programs. This information was further supplemented with inclusion of recent advancements made in harness designs, manufacturing techniques, etc.

Under the direction of Mr. Richard G. Smith, MSFC Saturn Program Manager, the responsibility for providing overall direction was assigned to the Quality and Reliability Assurance Laboratory, MSFC with the task of preparing the document assigned to North American Rockwell Corporation, Space Division. The task was formally defined as three subtasks:

- (a) Update of harness design Standard 40M39582,
- (b) Update of harness installations design Specification MSFC-SPEC-494, and
- (c) Derivation of the manufacturing and quality control processes volumes.

Formation of an AD HOC committee, comprised of representatives of MSFC Science and Engineering Laboratories (Astrionics, Astronautics, Process Engineering, and Quality and Reliability Assurance) for technical guidance, assured unity of input and compatibility between documents.

The task, as defined in Task Authorization 15 (TA 15) dated April 13, 1972 and amended by TA 15 C1, dated January 11, 1972, issued to North American Rockwell Corporation, Space Division, pursuant to NASA contract NAS7-200, was completed with delivery of report SA72-SA-0060 on July 31, 1972. The North American Rockwell Corporation Study Manager was Mr. W. L. Malohn, directly assisted by Messrs. J. Vandergriff, R. H. Parker, and E. J. Stringer.

## FOREWORD

This document is one of a series of four volumes prepared for use as a standard for manufacturing and quality control of interconnecting wire harnesses for space vehicle and payload applications.

The procedures reflected herein are based on the following four key elements:

1. Formulation of a typical manufacturing flow diagram for identification of each manufacturing and quality control process, operation, inspection and test point.
2. Identification of the various parts, materials, tools, and components, utilized in harness manufacture.
3. Acknowledgement of design standards as defined in MSFC document 40M39582, "Harness, Electrical Design Standard".
4. Acknowledgement of harness assembly installation standards defined in MSFC-SPEC-494, "General Specification for Installation of Harness Assembly (Electrical Wiring), Space Vehicle".

The complete series of documents covers the following harness types:

### Volume I

Type I	Enclosed in fluorocarbon elastomer convolute tubing
Type II	Enclosed in TFE convolute tubing lined with fiberglass braid
Type III	Enclosed in TFE convolute tubing
Type V	Combination of Type III and Type IV

### Volume II

Type IV	Open bundle (not enclosed)
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### Volume III

Type VI	Enclosed in TFE heat shrink tubing
Type VII	Flexible armored

### Volume IV

Type VIII	Flat conductor cable
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INTRODUCTION

1.1 SCOPE

The intent of this document is to establish uniform criteria to be used for acquisition, fabrication, and installation of Type IV - Open Bundle (not enclosed) space vehicle electrical harnesses, used for interconnecting wiring and cabling located outside the crew compartment area. This document shall be used as a basis for contractors and their suppliers to establish standard manufacturing and quality control techniques.

1.2 APPLICABILITY

This document identifies and describes the manufacturing process/controls, quality control inspection criteria, and test requirements that shall be used for the following major categories:

- a. Wire and Cable Preparation
- b. Harness Fabrication
- c. Harness Installation

1.2.1 APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or requests for proposals shall apply. This document shall take precedence over all other contractually imposed fabrication or inspection criteria and/or requirements relative in Type IV harnesses. In case of conflict between this document and the design documents 40M39582 and MSFC-SPEC-494, the design documents will take precedence:

40M39582 - Harness, Electrical Design Standard.

MSFC-SPEC-494 - Installation of Harness Assembly (Electrical Wiring),  
Space Vehicle, General Specification for.

NASA-NHB-5300.4 (1B) - Quality Program Requirements

NASA-NHB-5300.4 (3A) - Requirements for Soldered Electrical Connections.

### 1.2.1 APPLICABLE DOCUMENTS (Continued)

MIL-STD-202 - Test Methods for Electronic and Electrical Component Parts

MSC/MSFC-JD-001 - Crimping of Electrical Connections

### 1.2.2 APPLICABLE STANDARDS AND SPECIFICATIONS

The reference to applicable standards and specifications in the body of this document refers to NASA approved contractor's detailed procedures. Contractors may utilize these procedures if they meet or exceed the requirements set forth in this document. In case of conflict between this document and the contractor's procedures, this document shall take precedence.

Typical NASA documents which detail these procedures are listed below:

NASA SP-5002 - Soldering Electrical Connections

SR-QUAL-65-25 - Manufacturing and Quality Control Requirements for Space Systems Electrical Harnesses

SR-QUAL-67-20 - Apollo Saturn Stage Electrical Cable Installation Inspection Criteria

S&E-QUAL-70-4 - Crimping Electrical Connections

### 1.3 DEFINITIONS

For the purpose of this document, the following definitions shall apply.

1.3.1 Type IV - Open Bundle Harness. Shall consist of a group of wires, cables, or a combination of both, bundled together by lacing, spot ties, tie wraps, without a common covering and with two or more termination points.

Type IV - Open Bundle Harnesses shall be of the following styles:

1. Style A - Continuous Laced
2. Style B - Spot Tied
3. Style C - Tie Wraps
4. Combination of any two or more of the above styles.

1.3.2 Wire. - A single insulated conductor of solid or stranded construction without a shield, designed to carry current in an electrical circuit.

1.3.3 Cable. - Two or more insulated conductors, solid or stranded, contained in a common sheath, shield, or jacket; or two or more wires twisted or molded

**1.3.3 Cable - (Continued)**

**together with or without a common cover; or one or more insulated conductor  
with a metallic covering shield or outer conductor.**

## SECTION 2

### MANUFACTURING FLOW DIAGRAM

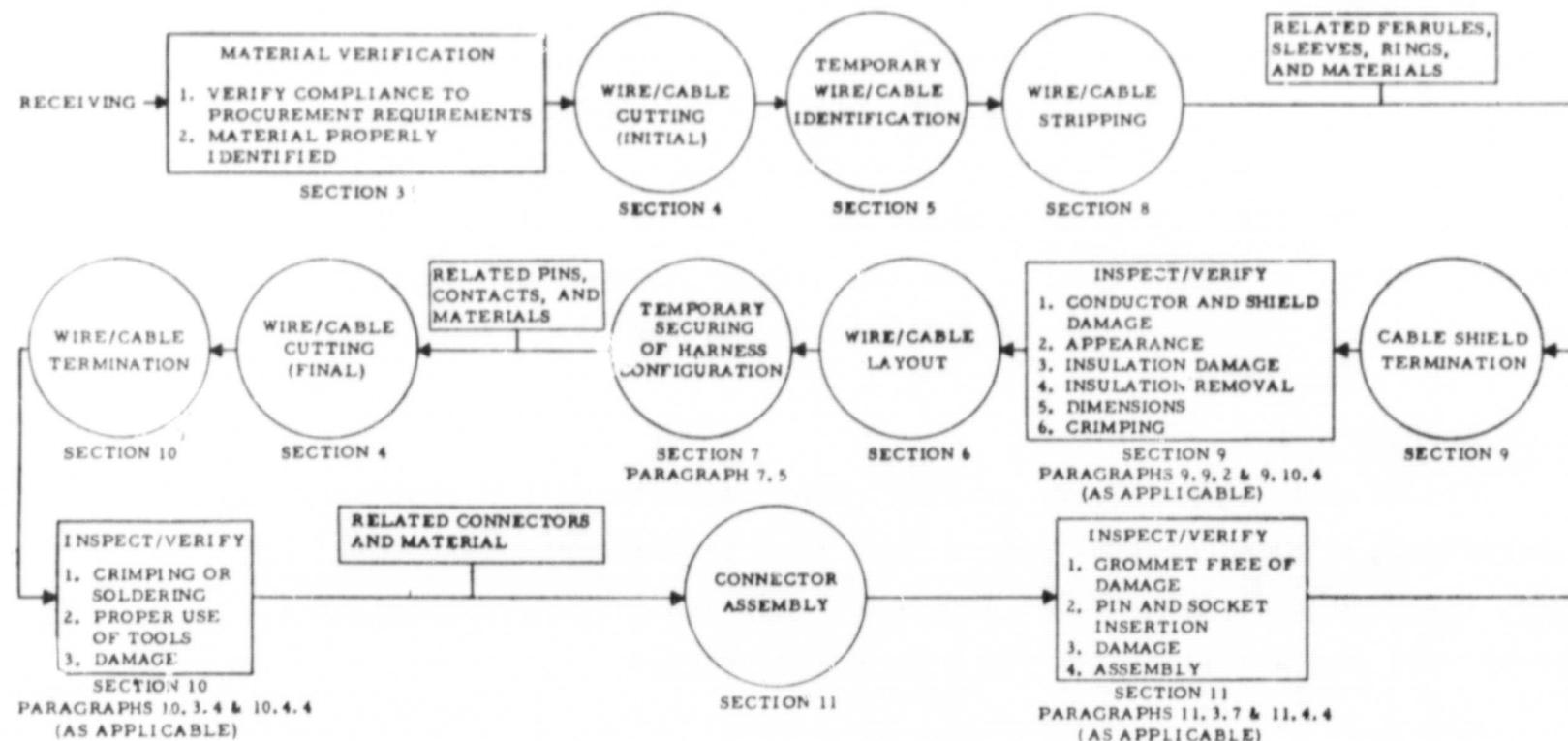
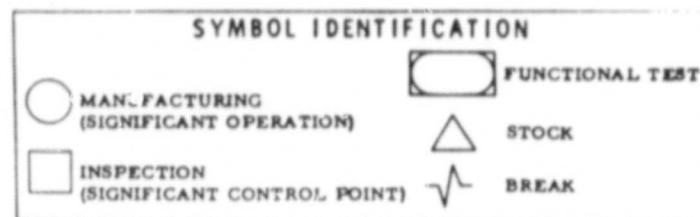
#### 2.1 SCOPE

The flow diagram contained in this section depicts one of several ways in which a harness may be manufactured. Variations to the suggested flow can result from harness configuration/design changes, assembly techniques, quantity of harnesses to be fabricated, and numerous other criteria. The enclosed diagram shall be used in conjunction with the manufacturing, process control, and test criteria contained in this document, as a guideline for manufacture of the applicable harnesses.

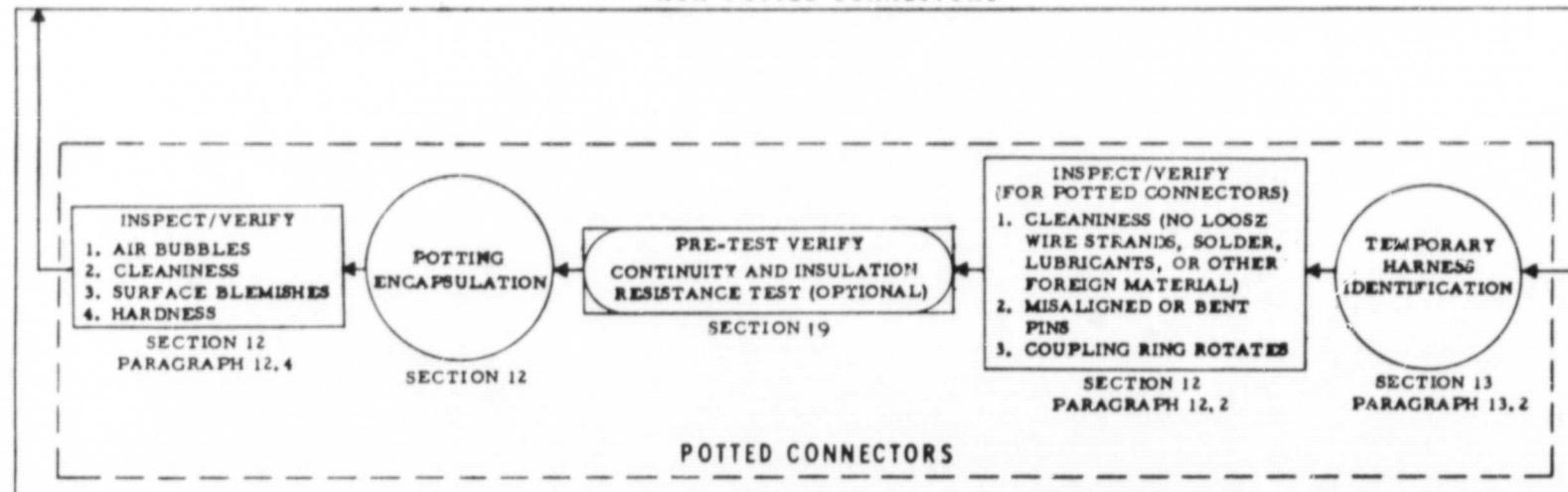
#### 2.2 APPLICABILITY

The diagram is a sequential flow chart identifying the manufacturing operations, process control points, and test requirements that shall be used for Type IV - Open Bundle (not enclosed) space vehicle electrical harnesses, for areas outside the crew compartment.

NOTE: THIS FLOW CHART DEPICTS ONE OF SEVERAL WAYS IN WHICH AN OPEN BUNDLE HARNESS MAY BE MANUFACTURED. VARIATIONS TO THE FLOW CAN RESULT FROM HARNESS CONFIGURATION/DESIGN CHANGES, ASSEMBLY TECHNIQUES, AND QUANTITY OF HARNESES TO BE FABRICATED.



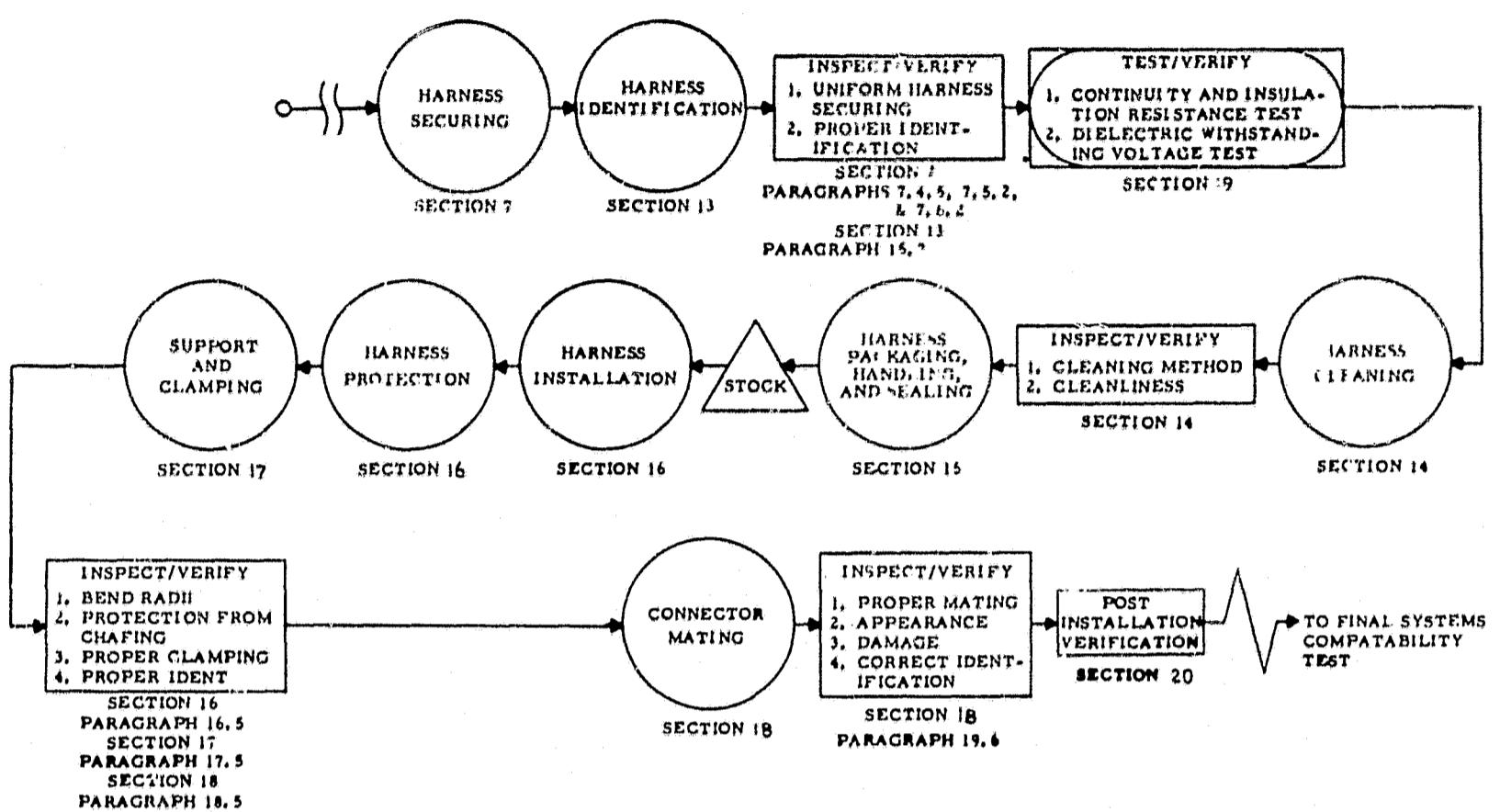
#### NON-POTTED CONNECTORS



#### POTTED CONNECTORS

{ } → **CONTINUED**

FLOW CHART 2-1 (TYPE IV-OPEN BUNDLE HARNESS)



FLOW CHART 2-1 CONTINUED (TYPE IV-OPEN BUNDLE HARNESS)

## SECTION 3

### RECEIVING INSPECTION

#### 3.1 GENERAL

This section describes the minimum requirements for inspection verification of electrical materials acceptance, prior to issuance for manufacturing operations.

#### 3.2 SCOPE

Electrical materials are those articles employed in fabrication and installation of interconnecting electrical wire/cable harness and consist of, but are not limited to, hookup wire and cable, coaxial cables, insulation sleeving, conductor and shield terminations (ferrules, sleeves, rings), connectors, clamps, tie-cord materials, potting materials, solder, fluxes, and associated materials.

#### 3.3 PURPOSE

The purpose of acceptance inspection is to assure that suppliers of production materials have adequately performed the required inspections and tests necessary to assure a quality product which meets procurement specification requirements. Acceptance inspection tests shall be conducted on a random sample, selected from each lot, batch, or group of materials submitted for acceptance at one time. Acceptance inspection tests shall not alleviate the supplier of his responsibility for performing all inspection and test requirements as specified in the procurement documents.

#### 3.4 REQUIREMENTS

The materials and associated articles procured for fabrication and installation of interconnecting space vehicle electrical harnesses shall meet the following requirements and any additional requirements specified by the procurement documentation,

##### 3.4.1 CERTIFICATION OF CONFORMANCE REPORT

When specified, certification prescribed by the procurement specification shall be reviewed for conformance to requirements.

### 3.4.2 SAMPLING FOR ACCEPTANCE

Sampling shall be defined as a length, group, or individual units randomly selected from a lot, batch, or group submitted for acceptance inspection and test at one time. Sampling shall be planned in accordance with NHB 5300.4 (1B), paragraph 1200, which provides direction for establishing and maintaining sampling plans.

### 3.4.3 EXAMINATION OF MATERIALS

Each inspection lot and type of material submitted for acceptance shall be given a careful visual and dimensional examination to determine compliance with the applicable procurement specification requirements. Dimensional inspection shall be made using micrometers, calipers, microscopes, or equivalent types of precision measuring instruments to determine product dimensional compliance. Materials shall be subjected to those tests as required to assure complete compliance to procurement specification acceptance and/or to validate conformance to paragraph 3.4.1. Examination of materials shall be performed in facilities as directed in paragraph 3.4.4.

### 3.4.4 FACILITIES

Facilities utilized for materials inspection and testing shall, as a minimum, satisfy the environmental and cleanliness levels directed by the procurement specification for the materials to be processed. Environmental and cleanliness controls shall be invoked to assure continued maintenance of prescribed levels.

## 3.5 WIRE AND CABLE

Wire and cable shall be subjected to a visual inspection to assure compliance with the detail procurement specification requirements (i.e., identification, contamination, evidence of damage, and general workmanship). Samples, as defined in paragraph 3.4.2, shall be subjected to the following inspection and tests, as prescribed in the detail procurement specification.

### 3.5.1 VISUAL EXAMINATION

Visually inspect wire and cable to assure compliance to the detail design requirements. As a minimum, the following condition shall be inspected for:

- a. Outer insulation cracking or flaking.
- b. Damaged wire insulation.

### 3.5.1 VISUAL EXAMINATION (Continued)

- c. Burned or charred insulation.
- d. Incorrect insulation material.
- e. Nicks, rings, scrapes, or scratches on outer conductor strands, through plating.
- f. Insufficient number of strands.
- g. Tarnished or corroded wire.
- h. Untwisted lay of strands.
- i. Broken and/or loose shield strands.
- j. Incorrect type or class insulation or sheath.

### 3.5.2 ELECTRICAL TESTS

As a minimum for acceptance, wire and cable shall be subjected to the following electrical tests in compliance with the detail design procurement specification:

- a. Dielectric withstanding voltage test
- b. Insulation resistance test
- c. Conductor D.C. resistance test

### 3.6 ELECTRICAL CONNECTORS

Each connector shall be subjected to a comprehensive visual examination, for compliance with the detail procurement requirements, correct identification, and to assure that the connectors are free of contamination and/or damage. Connectors shall be packaged to provide protection from mishandling, contamination, and accelerated aging during storage. As a minimum, the following unsatisfactory conditions shall be inspected for:

- a. Imperfections in grommets extending into the chamfer area.
- b. Obvious cuts or gouges which may reduce the sealing ability of the grommet.
- c. Obvious splits and misaligned grommets.
- d. Mold flashes extending into pin (contact) hole.
- e. Missing or improper "O" rings.
- f. Tarnished or corroded contacts.
- g. Nicks, rings, scrapes, or scratches.
- h. Cracking or flaking of plating.
- i. Wrong type plating.
- j. Visible dirt, grease, or other foreign materials.

### 3.7 POTTING MATERIALS

Potting materials shall be randomly sampled and tested to assure compliance with the detail procurement requirements. The following criteria shall be inspected as a minimum:

- a. Hardness
- b. Accelerated pot life
- c. Adhesion
- d. Shelf life identification
- e. Storage requirements
- f. Electrical requirements (when applicable)
- g. Tensile strength

### 3.8 INSULATION SLEEVING

Insulation sleeving materials shall be sample inspected to assure conformance to the detail procurement specification. The following tests shall be conducted as a minimum for acceptance:

- a. Dimensional compliance, as received and after heat application.
- b. Longitudinal shrinkage.
- c. Dielectric withstanding voltage test.
- d. Material identification

### 3.9 COAXIAL CABLE

Coaxial cable shall be subjected to those acceptance requirements as noted in the detail procurement specification, and as a minimum, be subjected to the following inspections and tests:

- a. Dimensional compliance (i.e., dielectric and jacket thickness).
- b. Shield braid coverage.
- c. Attenuation and impedance.
- d. Identification marking.

### 3.10 CONDUCTOR AND SHIELD TERMINATIONS

Each lot, batch, or group of conductor terminations (ferrules, sleeves, rings, etc.) submitted for acceptance shall be randomly sampled and inspected for the following criteria, as a minimum:

- a. Dimensional compliance.
- b. Tarnished or corroded contacts.
- c. Wrong type plating.

3.10 CONDUCTOR AND SHIELD TERMINATIONS (Continued)

- d. Visible dirt, grease, or other foreign materials.
- e. Cracking or flaking of plating.
- f. Insulated ferrule damage.

3.11 SOLDER AND SOLDER FLUX

Each lot or batch of solder and/or flux shall be required to have a certification of compliance and chemical analysis data submitted with each receipt. In addition, the following criteria shall be inspected as a minimum:

- a. Correct identification marking in accordance with the detail procurement specification.
- b. Each spool, box, or can, adequately marked with a batch or lot number.

3.12 TIE-CORD MATERIALS

Each lot or batch of tie-cord submitted for acceptance shall be inspected for correct identification to type and class of material.

3.13 WIRE/CABLE SUPPORT CLAMPS

Wire and cable harness support clamps shall be submitted to a detail physical examination to determine the following criteria, as a minimum:

- a. Assure clamp dimensional configuration on a randomly selected sample.
- b. Clamp cushion material shall be free of gouges that expose the metal clamp and cuts or cracks running parallel to the clamp center line.
- c. Clamp cushion material shall be of the type specified on the procurement specification.

3.14 OTHER ASSOCIATE MATERIALS

The other materials used in the fabrication and installation of interconnecting wire/cable harnesses shall be subjected to the inspections and tests necessary to assure conformance to the procurement specification requirements.

As a minimum, the following criteria shall be inspected for:

- a. Adequate identification markings.
- b. Dimension configuration, when applicable.
- c. Workmanship.
- d. Packaging and protection necessary to assure that no degradation occurs during normal storage and handling.

## SECTION 4

### WIRE AND CABLE CUTTING

#### 4.1 GENERAL

All wires and cables shall be cut to approximate length prior to layout, and to prescribed length, as dictated by harness design requirements, after layout and temporary securing of harness configuration. Wire and cable cutting equipment of either automatic or manual operation may be utilized. In addition, it is sometimes necessary to cut wire or cable using acceptable hand cutting tools. Regardless of the method used (automatic, manual, or hand), it is essential that the cut wire or cable meet the requirements contained in the following paragraphs.

#### 4.2 PROCESS CONTROL REQUIREMENTS

Prior to cutting of the electrical wire and/or cable, verify correct type in accordance with applicable drawing, including size, type plating, and insulation. Make sure wire/cable has undergone receiving inspection criteria established in paragraph 3.5 of this document. Record lot number of wire/cable on In-Process Control Documentation. Close visual examination shall be performed on the wire/cable as unreeled from the spool. As a minimum, the following conditions shall be inspected for:

- a. Outer insulation cracking or flaking.
- b. Damaged wire insulation.
- c. Incorrect insulation material.

##### 4.2.1 CLEANLINESS

The work area used for cutting wire and cable shall exhibit a clean and orderly appearance. All dirt, grease, oil, chips, and other foreign material shall be removed from tools, equipment, and work areas.

##### 4.2.2 EQUIPMENT/TOOL REQUIREMENTS

Hand or machine cutting equipment and tools shall be periodically certified per NHB 5300.4(1B). A sticker or other device shall be attached to each tool or piece of equipment indicating certification and the next recertification due date. The work produced shall be checked to assure that the insulation

#### 4.2.2 EQUIPMENT/TOOL REQUIREMENTS (Continued)

has not been punctured, crushed, or otherwise damaged, and that the wire/cable ends are cut square. Cutting efficiency shall be maintained by replacing blades and calibrating when necessary.

#### 4.3 WIRE/CABLE CUTTING OPERATIONS

The cutting operations shall be performed in such a manner that the conductor strands, shielding (where applicable), and insulation are not damaged adjacent to the cut end. Wire cutting equipment or tools shall not cut, extrude, or otherwise damage adjacent insulation. Frayed insulation at cut wire or cable ends is unacceptable, although a few fibrous threads of fiber may be allowed to remain providing they do not interfere or represent more than 10% of the total fiber stranding. Repetitive occurrences of improper cutting of the wire/cable, or damage to the insulation, shall be cause for maintenance and/or re-calibration of the equipment.

## SECTION 5

### TEMPORARY WIRE AND CABLE IDENTIFICATION

#### 5.1 GENERAL

This section describes the procedures that shall be used for temporary identification of wires and cables, when desired. Temporary wire and cable identification is not a requirement established by this document, but is included for the purpose of providing an assembly aid during the fabrication and test cycles. If a temporary method of wire and cable identification is utilized, care shall be exercised to ensure that the wires or cables are not damaged by the identification procedure. In addition, precautions shall be established to ensure that all temporary identification is removed prior to installation.

#### 5.2 PROCESS CONTROL REQUIREMENTS

Prior to application of temporary wire and cable identification markers, verify that all wire and cable outer insulation is free of surface damage and/or contamination. Examine the wire and cable to be identified to assure the correct type, class, or size, as specified on the applicable engineering documentation. Verify the wire/cable has been cut to the requirements of Section 4 for cutting of electrical wire and cable.

#### 5.3 IDENTIFICATION METHODS

The combination of letters and numbers which constitute the wire/cable identification code shall be in accordance with applicable manufacturing standards. The identification marker shall be of the type that can be slipped onto the wire/cable easily and will grip the wire/cable firmly, but without causing damage (i.e., impressions, cuts, abrasion, etc.) to the insulation. In addition, the marker(s) shall be of the type that can be removed without cutting. It is suggested that identification markers of the split sleeve, or tag type be used. Markers that rely on adhesive backing to adhere to the wire/cable insulation shall not be attached to the harness,

### 5.3 IDENTIFICATION METHODS (Continued)

due to the possibility of adhesive residue remaining on the insulation after removal of the markers. An alternate means of temporarily identifying wire and cable is achieved by allowing each conductor an additional length of wire adequate for the attachment of an identification marker. This marker, placed near the end of the conductor, is subsequently removed when the excess conductor length, bearing the marker, is cut off.

### 5.4 LEGIBILITY

All identification characters on markers should be legible, permanent, and colored to contrast with the surface on which the identification is placed. In addition, the characters should be of sufficient size and color to provide ease of identification.

## SECTION 6

### WIRE AND CABLE ROUTING

#### 6.1 GENERAL

This section establishes the fabrication criteria that pertains to grouping, layout, and bundling of wires and/or cables into a complete harness assembly. Several other elements relative to harness fabrication such as wire/cable preparation (cutting, identification, stripping, and termination) and harness fabrication (securing, identification, and protection) are covered elsewhere in this document and should be referred to where applicable.

#### 6.2 PROCESS CONTROL REQUIREMENTS

Prior to performing wire and cable layout operations, verify correct type of wire/cable and that preceding cutting and stripping (if applicable) operations have been properly performed. Make sure that wires/cables have not been damaged and necessary process control verification has been performed. In addition to the preceding process control requirements, the control and handling precautions described in the following paragraphs shall be applied.

##### 6.2.1 CONTROL AND CLEANLINESS OF MOCKUP AREAS

All mockup of electrical wiring shall be performed in a controlled area. The general working area and benches shall be maintained in a clean and orderly condition at all times. Only tools, fixtures, equipment, etc., which are required to perform the task shall be allowed in the area. Supply cabinets or shelves used to store electrical wire, cable, components, hardware, etc., shall be set aside from the immediate work area, and shall be maintained in a clean and orderly condition to avoid contamination of the electrical wiring and associated materials being assembled.

##### 6.2.2 WIRE AND CABLE PROTECTION

All mockup boards or fixtures shall be inspected for sharp edges, protrusions, and any other conditions that may damage wire and cable

#### 6.2.2 WIRE AND CABLE PROTECTION (Continued)

insulation. All metallic guides and supports shall be covered with protective sleeving or coating.

#### 6.3 FABRICATION AND HANDLING PRECAUTIONS

The fabrication and handling of wires, cables, and harness assemblies requires reasonable care to prevent damage and to assure cleanliness. In addition to the handling and packaging procedures described in Section 15, the following precautions shall be observed:

- a. Wires, wire harness assemblies, and cables shall be fully supported at all times. They shall not be allowed to hang over the edges of work surfaces or to lay on protrusions that may cause damage to conductors or insulation. In no instance will they be placed on a surface, such as a floor, where they may be stepped on or damaged by vehicular traffic. Tools or other foreign objects shall not be layed on wire, wire harness assemblies, or cables during fabrication or stowage.
- b. During handling, care shall be exercised to prevent wires, wire harness assemblies, and cables from being dragged over any surface. They shall be fully supported and lifted when moved.
- c. Removal of temporary ties may be accomplished by the use of diagonal cutters or "hipper-type" scissors. The cutting instrument shall not be inserted between wires to facilitate cutting. Spot ties may be easily removed by cutting off the finish knot.

##### 6.3.1 CLEANLINESS PRECAUTIONS

Incomplete wires, cables, and harness assemblies not in work (on benches or jig boards) shall be completely covered with polyethylene film or equivalent that will not degrade the intent of the completed harness. Work areas shall be clean at all times. Wire cuttings, pieces of insulation or tying material, and foreign material shall be cleared from the area as they occur. Only tools in use shall be allowed on the working surfaces of benches and jig boards.

#### 6.4 LAYOUT

To facilitate installation and maintenance, route wires/cables in an orderly fashion with individual wires and cables in a bundle generally parallel.

#### 6.4 LAYOUT (Continued)

Avoid crossovers, snarls, tangles, or kinks. Refer to Figure 1, for typical wire/cable layup. When laying out electrical wires and cables, caution shall be exercised to avoid abrasion, cutting, or piercing of the insulation by contact with rough surfaces, or sharp edges.

##### 6.4.1 HARNESS BRANCH BREAKOUT PROCEDURE

It is preferred that harness branch breakouts emerge from the main bundle body in such a manner that the axis of each breakout branch remains straight. Breakouts from the main bundle shall be performed with a minimum of crossed wires or cables. Wire/cable bundles shall be dressed and parallel from their point of origin to their termination point.

##### 6.4.2 TWISTED WIRES

If specified by engineering drawing, hand twist wires into a wire pair. When twisting is specified, it shall begin as close to the termination as practical without causing undue stress on the connector terminations, support, or branch point (preferably within six inches). The twisting operation shall be performed as follows:

- a. Route and straighten wires as described in paragraph 6.4.
- b. Determine the point along the harness bundle at which twisting shall begin.
- c. Begin twisting the wires in one direction using Figure 2 and Table I for determining length of lay (turns per foot).

##### 6.4.3 BEND RADIUS

The minimum radius of bend shall not cause wire or cable insulation disruption nor affect normal wire/cable life or characteristics. The bend radius of a harness formed during fabrication on a jigboard shall not be less than three times the diameter of the largest wire/cable in the bundle, if all wires or cables are 10 gage or smaller; and not less than six times the diameter of the largest wire or cable in the bundle, if there are wires or cables larger than 10 gage, or coaxial cables. Bends in wire harnesses shall be made with the bundles untied to minimize tight wires or cables, and the radius of bend shall not extend into the terminating device.

## **6.5 APPEARANCE**

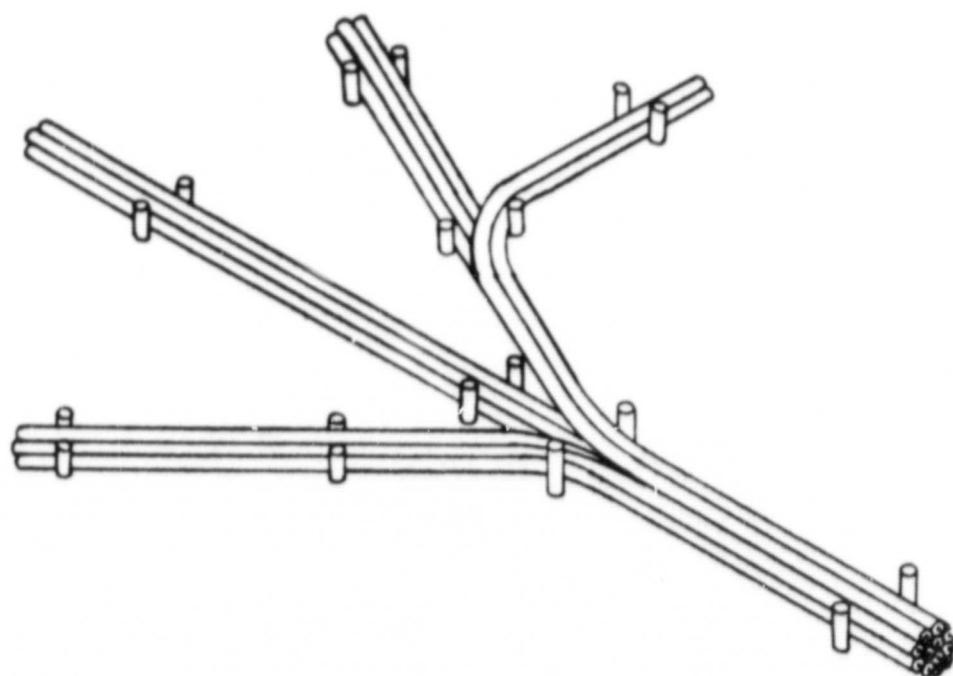
Wire harnesses shall have a neat, orderly appearance such as is achieved by combing of the wires and by progressive, lacing, spot tying, or tie wrapping. Breakouts from the bundle shall be formed with a minimum number of crossed wires. Knots, kinks, loops, or splices, are not permitted in wire or cable runs unless specified by design.

## **6.6 INSPECTION, REQUIREMENTS**

Wire/cabling harness mockup units shall be inspected in accordance with all applicable specifications and drawings. Mockup boards or fixtures shall be subjected to an examination to verify dimensional accuracy and be controlled to assure approval and documentation of all changes or revisions.

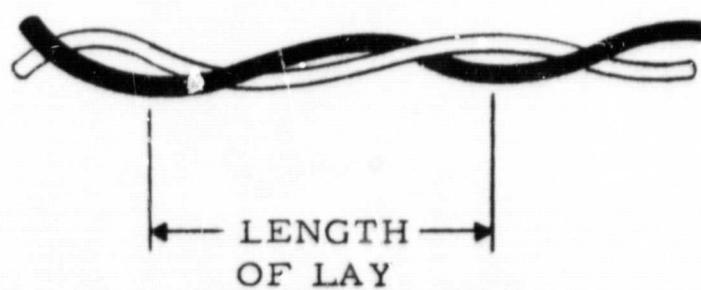
WIRE SIZE	MAXIMUM TURNS PER FOOT	MINIMUM TURNS PER FOOT
26	20	16
24	18	14
22	16	12
20	14	10
16	12	9
14	10	7
12	8	5
8	4	3

TABLE 6-1  
TURNS PER FOOT FOR TWISTING WIRE



**FIGURE 6-1 TYPICAL WIRE/CABLE LAY UP**

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**FIGURE 6-2 TYPICAL TWISTED WIRES**

SECTION 7  
HARNESS SECURING

7.1 GENERAL

Lacing tape or harness straps shall be used to contain wires and cables in an orderly bundle, to reduce or eliminate vibration, and to relieve strain on individual wires or cables. This section provides general information on acceptable harness securing methods and the procedures to be used.

7.2 REQUIREMENTS

All harnesses which are not enclosed in conduit or other protective covering shall be continuously laced or tied to provide a secure bundle configuration. As an alternate method, harness straps may be used, if approved, in lieu of lacing or tying. Wire harnesses shall be secured tight enough to prevent slipping, but not so tight that the tying material or strap cuts into the wire/cable insulation. Laces or ties used on harnesses containing Teflon insulated wires or cables will have a tendency to rotate and move laterally during handling, and need not be tight enough to prevent this movement.

7.2.1 PROCESS CONTROLS

Prior to securing wire and cable into the required harness configuration, assure that all wire and cable is routed correctly to avoid crossovers, snarles, tangles, or kinks, and any required conductor separation is maintained. Verify that breakouts contain a minimum of crossed wires or cables and are dressed correctly. Inspect the work area and harness layout to assure there are no wire cuttings, pieces of insulation, or other foreign material present. Verify that the lacing tape is the correct type and/or class as specified on the applicable drawing and shows evidence of previous acceptance by receiving inspection.

### 7.2.2 SECURING METHODS

Lacing tape or harness straps shall be used to contain groups of wires/cables into a wiring bundle, but the tape or straps shall not be used to support the harness. Open bundle harnesses shall be secured in accordance with one of the following methods:

- a. Continuous laced
- b. Spot tied
- c. Tie wraps
- d. Combination of any two or more of the above styles

### 7.3 SECURING INTERVALS

Assemblies being secured in accordance with the listed methods shall have lacing ties, spot ties, or tie wraps spaced as indicated in Table 1 to provide a neat and securely held wire harness. At sharp bends in the harness, the spacing between lacing stitches, spot ties, or tie wraps shall be shortened to provide a better lacing dress.

#### 7.3.1 SECURING INTERVALS FROM CONNECTORS

When securing wire bundles behind connectors, the distance from the connector to the first tie shall be as specified in Table 1. The minimum requirements given in Table 1 do not apply to wire harnesses which are held rigid with potting compound at their connector termination points. The first wire harness tie, however, must be close enough to the connector support point to relieve undue tension on any individual wire or cable.

### 7.4 CONTINUOUS LACED METHOD

Securing of wire harnesses utilizing the continuous laced method shall only be performed when the harness is long enough to accommodate the termination of lacing, distances between connector and termination of the lacing, and distance required for at least two complete stitches.

#### 7.4.1 LACING MATERIAL

All lacing cord used for securing open bundle wire harnesses shall be as specified on the applicable drawing or specification. Lacing material shall withstand the same temperatures and other environmental conditions to which the wire harness is subjected.

#### 7.4.2 LACING PROCEDURE

The continuous laced method of securing wire harnesses consists of starting and terminating sections of wound lacing cord using single lock stitch and running hitch stitching in accordance with Figures 1 and 2, and the following procedure:

- a. Cut loop tape (a piece of tape approximately eight inches long), fold in half and lay aside within reach.
- b. Unwind estimated length of lacing tape necessary to wrap the assembly and place tape parallel on assembly starting at a position to meet the requirements of Table 1. The tape shall be held in place by hand and the end of the tape shall be wound around the assembly and itself, away from the end of the assembly. Wind a minimum of three turns or to the center of the termination (maintain tight wrap).
- c. Feed the tape end through assembly, dividing the conductors into two equal groups, then continue winding an equal number of turns.
- d. Lay loop tape on the layer of winding parallel to conductors with the loop tape toward the end of the assembly or past the first turn.
- e. Repeat a second layer of winding in the same direction, returning over the first layer and the loop tape. The last turn shall cover the first turn.
- f. Feed the loose end of the lacing tape through the loop, hold the end of the tape tight while pulling the loop to the center of the termination, spread the loose ends forming a cross between the two layers locking the lacing in place. Trim all the loose ends. The finished termination should be as shown in Figure 2E.
- g. Lace the complete assembly using the single-lock stitch as shown in Figure 3.
- h. The lacing shall be terminated in the same manner as the starting section shown in Figure 4.

#### 7.4.3 LACING TAPE SPLICE TERMINATION

The splice termination shall be performed only on long harness assemblies when the tape is damaged or broken 10 feet or more from the originating end, and may also be required in two places to replace a damaged section of the

#### 7.4.3 LACING TAPE SPLICE TERMINATION (Continued)

lacing. The tape ends shall be placed parallel to the cable in opposite directions and the lace end serve wrapped over the splice tape and over itself as in the terminating serve first layer; then the lace end is placed under the splice tape and formed in a loop to the opposite side of the serve as shown in Figures 5A and 5B. Hold the loop in position and wrap the second layer with the splice tape in the opposite direction until the serve reaches the edge of the start of the first wrap, pass the end through the loop as shown in Figure 5C, and pull loop under second layer to the center of the serve, form an X lock by positioning the loose tape ends. Cut off excess tape as shown in Figure 5D, and continue the lacing process.

#### 7.4.4 LACING BRANCHES AND BREAKOUTS

When a harness contains branches or breakouts, the following procedures shall apply:

- a. Where practicable, the main trunk of the wire bundle or harness shall be continuously laced between connectors or components. The main trunk is the portion containing the largest number of wires, as shown in Figure 6, reference A.
- b. A terminating section, as described in 7.4.2, shall be performed on the main trunk of the harness or wire bundle at the beginning of a wire branch, as shown in Figure 6, reference B.
- c. The branch shall be continuously laced, beginning at the junction, as shown in Figure 6, reference C.

#### 7.4.5 ACCEPTABLE LACING CRITERIA

Inspect the location and length of the starting and terminating serve. The serve location with respect to the connector rear face or wire guide shall be as specified in Table 1. Conductors in the area between the starting or terminating serve and the connector, should be reasonably parallel to each other with no birdcaging or excessive entwining of wires. There shall be no looping or kinking of wires/cables due to excessive lengths. All lacing shall be inspected for snugness; however, lacing shall not be so tight as to cut or rupture the wire/cable insulation material.

## 7.5 SPOT TIED METHOD

The spot tie method of securing wire harnesses shall be used for permanently securing wire bundles or as a temporary securing method.

### 7.5.1 SPOT TIE MATERIAL

All spot tie cord used for permanently securing open bundle wire harnesses shall be as specified on the applicable drawing or specification. Temporary spot ties, such as those necessary for handling, may be prepared using material that does not damage or contaminate the harness assembly. These ties shall be removed prior to completion of the wire harness assembly.

### 7.5.2 PROCEDURE

When spot ties are used, they shall consist of at least two complete turns of lacing tape around all the conductors being tied. The lacing tape shall be secured with a suitable non-slip knot to prevent movement of the tie during handling of the assembly. The tie shall be performed as illustrated in Figure 7, and in accordance with the following procedure:

- a. Holding a short length of lacing tape parallel with the conductors (Fig. 8,A & B), wrap two turns of lacing tape loosely around the complete assembly. The first turn should lap over the parallel section, and the second turn should run under the parallel section, as shown in Figure 8, reference C.
- b. Pull the ends of the lacing tape, as shown in Figure 8, reference D, so that the turns are snug.
- c. Tie a terminating knot with loose ends of the lacing tape, as shown in Fig. 8,E. The knots shall be installed so that the wires are tightly bound together, but remain undamaged by the tape. A second square knot may be tied on top of the first square knot when considered necessary (Ref. Fig. 9.A & B).
- d. Trim the loose ends of the lacing tape so they are approximately 1/4 inch in length (Fig. 8, ref. F).

### 7.5.3 ACCEPTABLE SPOT TIE CRITERIA

Wire shall be secured in a harness or bundle by tying material utilizing the method described in paragraph 7.5.2. The cut ends of the tying material

### 7.5.3 ACCEPTABLE SPOT TIE CRITERIA (Continued)

shall extend approximately 1/4 inch from the knot. Each step of the knot is to be pulled tight prior to starting the next step. Since glass fiber material will loosen under handling, it is essential that a double square knot is used. Only visual examination should be used to detect loose spot-tie knots and handling should be avoided. The spot-tie spacing and location with respect to the connector shall be as specified in Table 1.

### 7.6 TIE WRAP METHOD

Plastic or nylon harness tie wraps of an approved source may be used on open bundle wire harnesses. The tie wraps shall be mounted snugly on the assembly wires/cables and be capable of being locked to prevent loosening or opening. The tie wraps shall be positioned to correspond with the location intervals specified in Table 1, and as illustrated in Figure 10.

#### 7.6.1 ACCEPTABLE TIE WRAP CRITERIA

Each tie shall be installed with the proper tool. The tie shall be pulled tight enough to support and secure the harness, but not tight enough to damage insulation. After the tie-wrap end is locked in place by a 90 degree rotation of the tool, the excess end shall be cut off flush to prevent damage to other wires/cables and to personnel. Check for tightening of the tie by gently attempting to slide the wire/cable in the tie. There shall be no evidence of wire/cable insulation damage or deforming due to the installation of the ties. The tie wrap spacing and location with respect to the connector shall be as specified in Table 1.

### 7.7 LACING TAPE AND TIE WRAP REMOVAL

To eliminate the possibility of damage to the wire/cable insulation, use only approved cutters, which have a smooth rounded face with no sharp edges.

**CAUTION:** Care shall be taken when securing Teflon insulated wire and cable, since excessive pressure may result in a decrease in insulation thickness due to cold-flow of the Teflon material.

HARNESS DIAMETER	DISTANCE BETWEEN CONNECTORS AND START OF TIE
0.5 or less	0.75
0.5 - 1	1.00 - 1.25
1.0 or larger	1.25 - 2.00

NOTE: <sup>1</sup> The spacing between spot ties or tie wraps shall be equal distance but shall not exceed 2.00 inches.

<sup>2</sup> Dimensions shall be from the rear face of the connector or wire guide. The distance shall be measured along the approximate centerline or the bend.

TABLE 7-1 TYINC DIMENSIONS

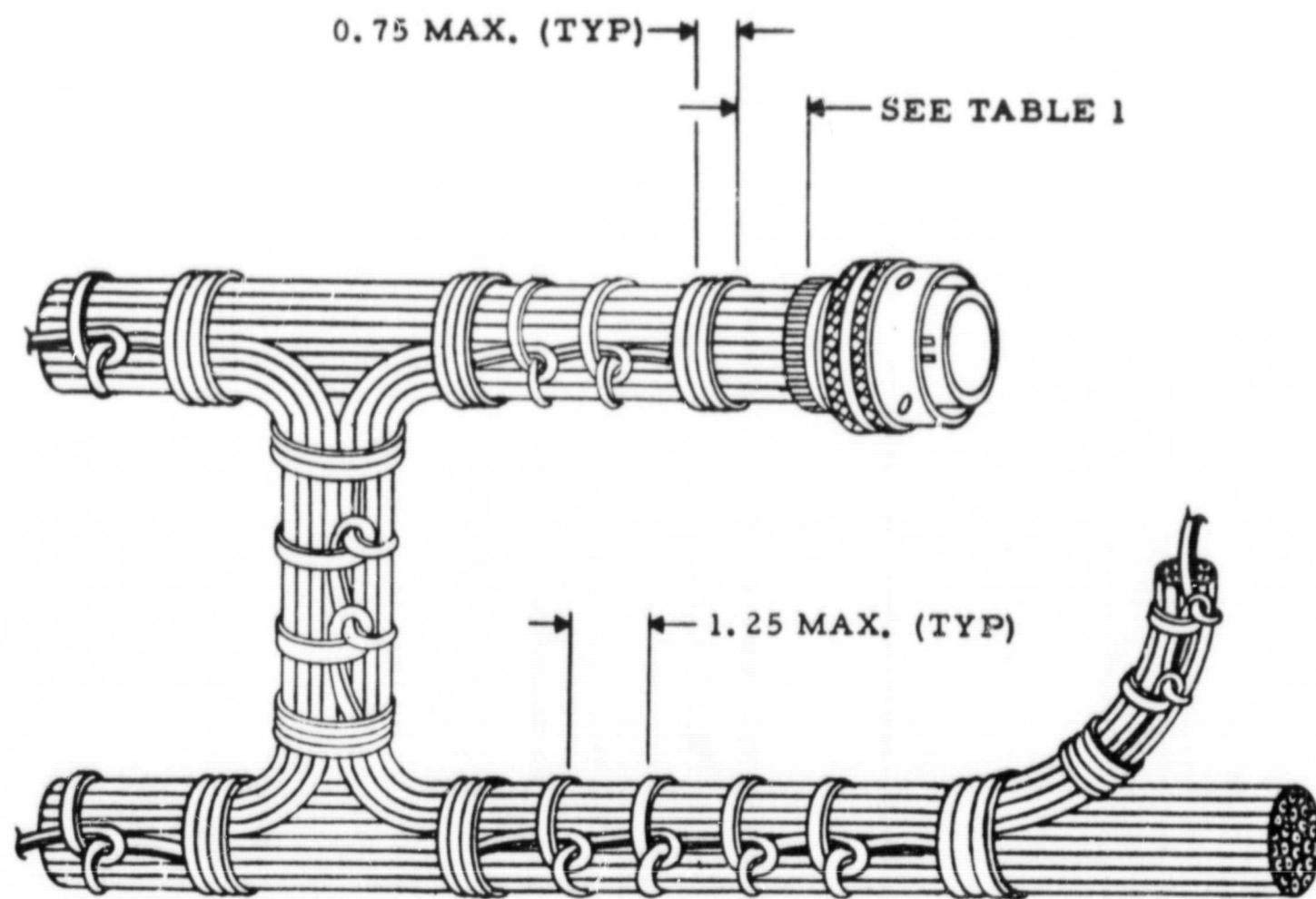
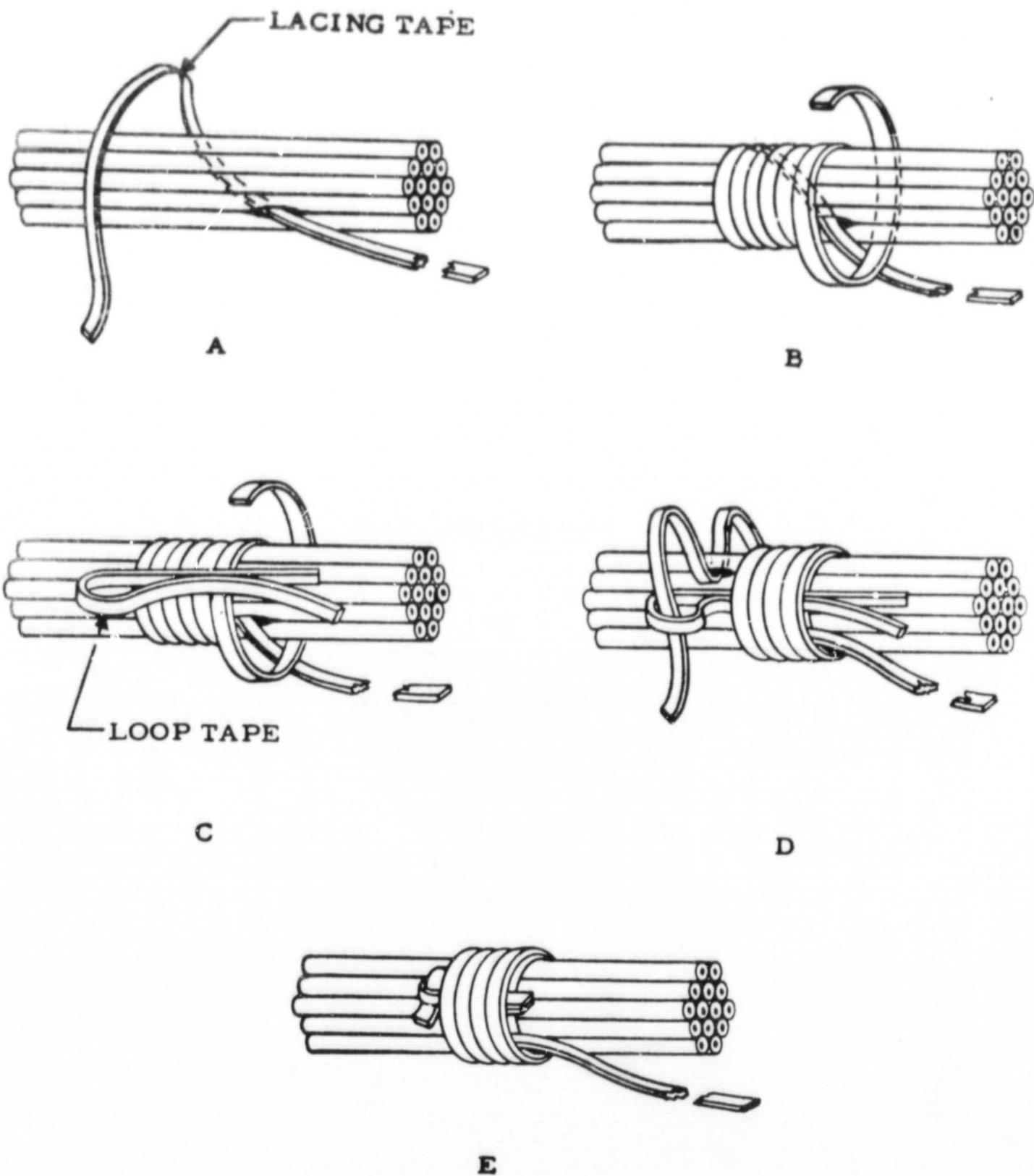
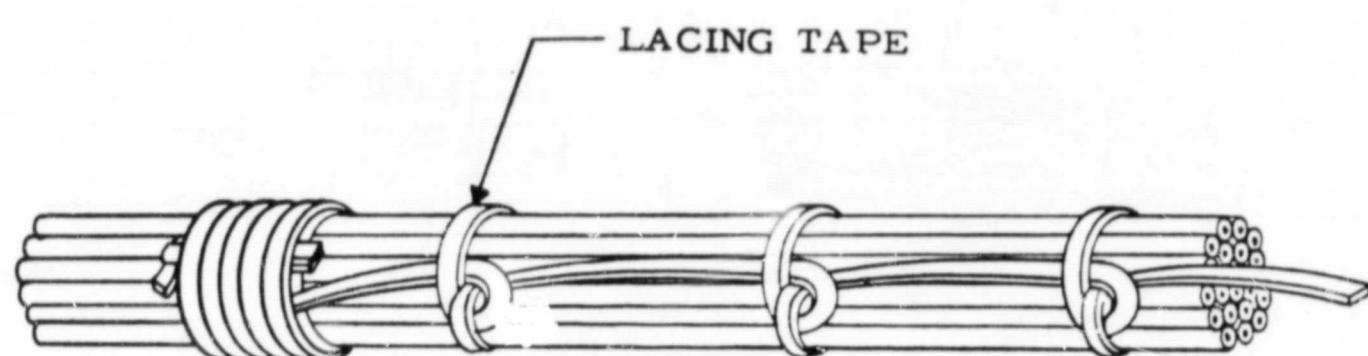


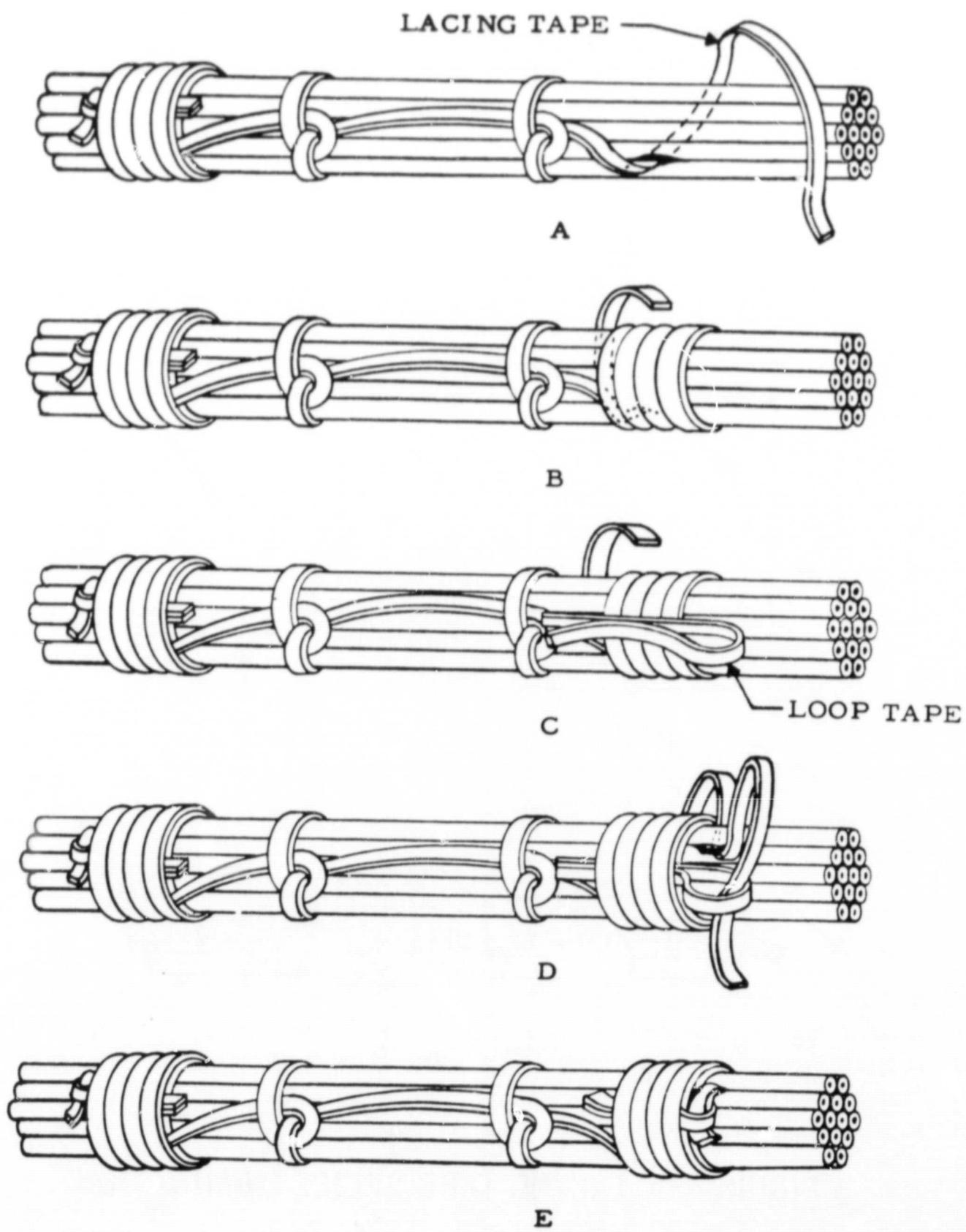
FIGURE 7-1 STYLE A SECURED HARNESS



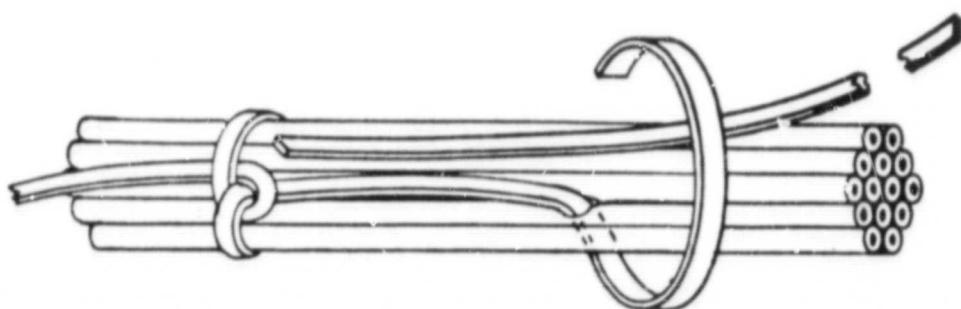
**FIGURE 7-2 LACING STARTING SECTION**



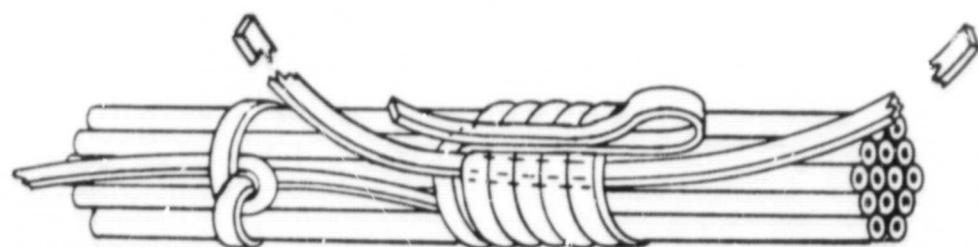
**FIGURE 7-3 SINGLE-LOCK STITCH**



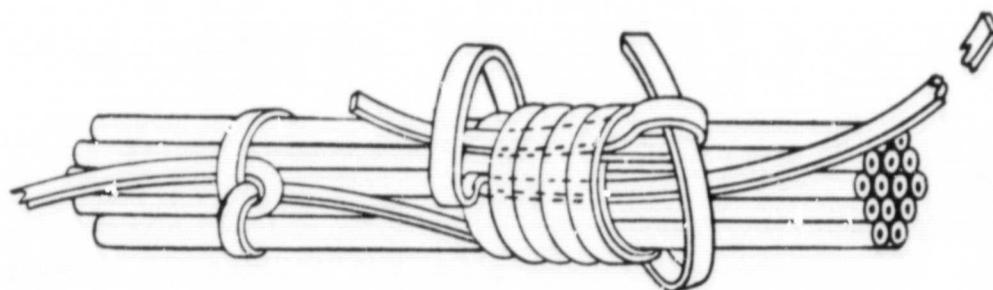
**FIGURE 7-4 TERMINATING LACING SECTION**



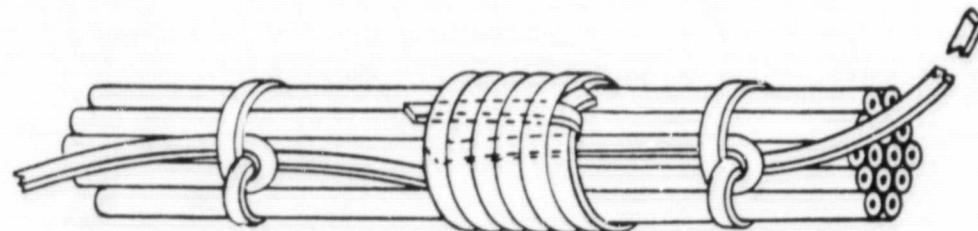
A



B

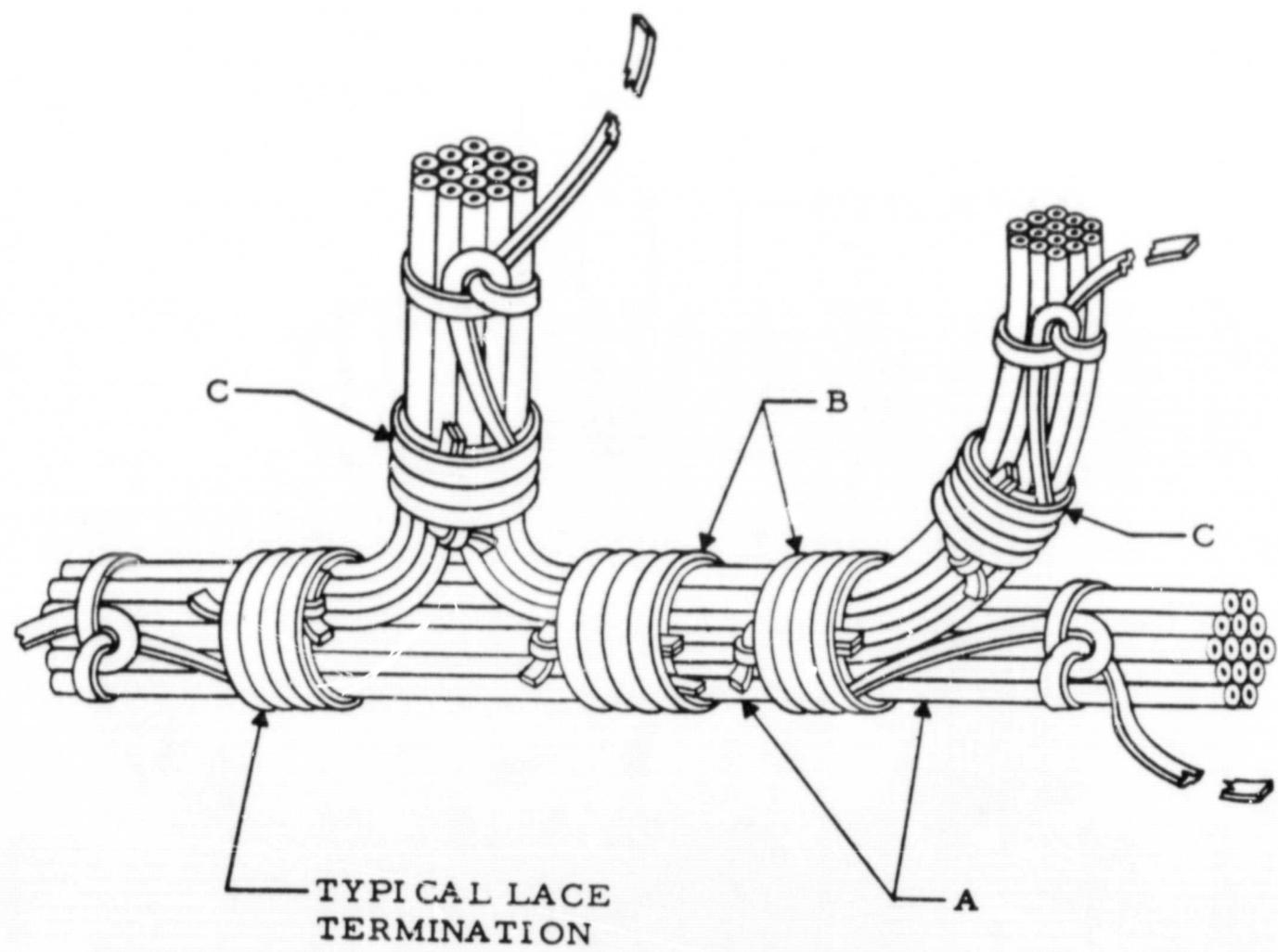


C



D

**FIGURE 7-5 LACING TAPE SPLICE TERMINATION**



**FIGURE 7-6 LACING BRANCHES OR BREAKOUTS**

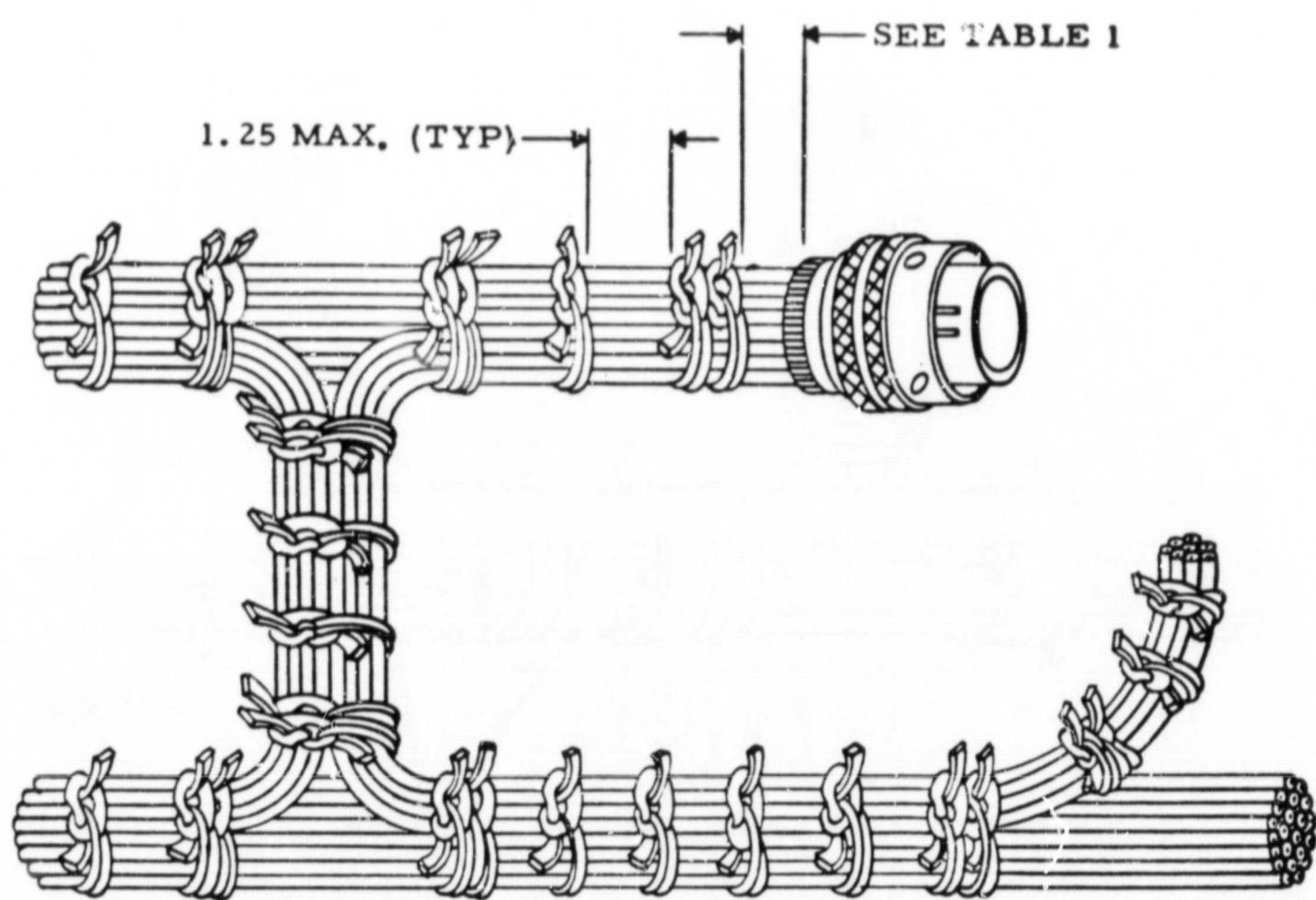
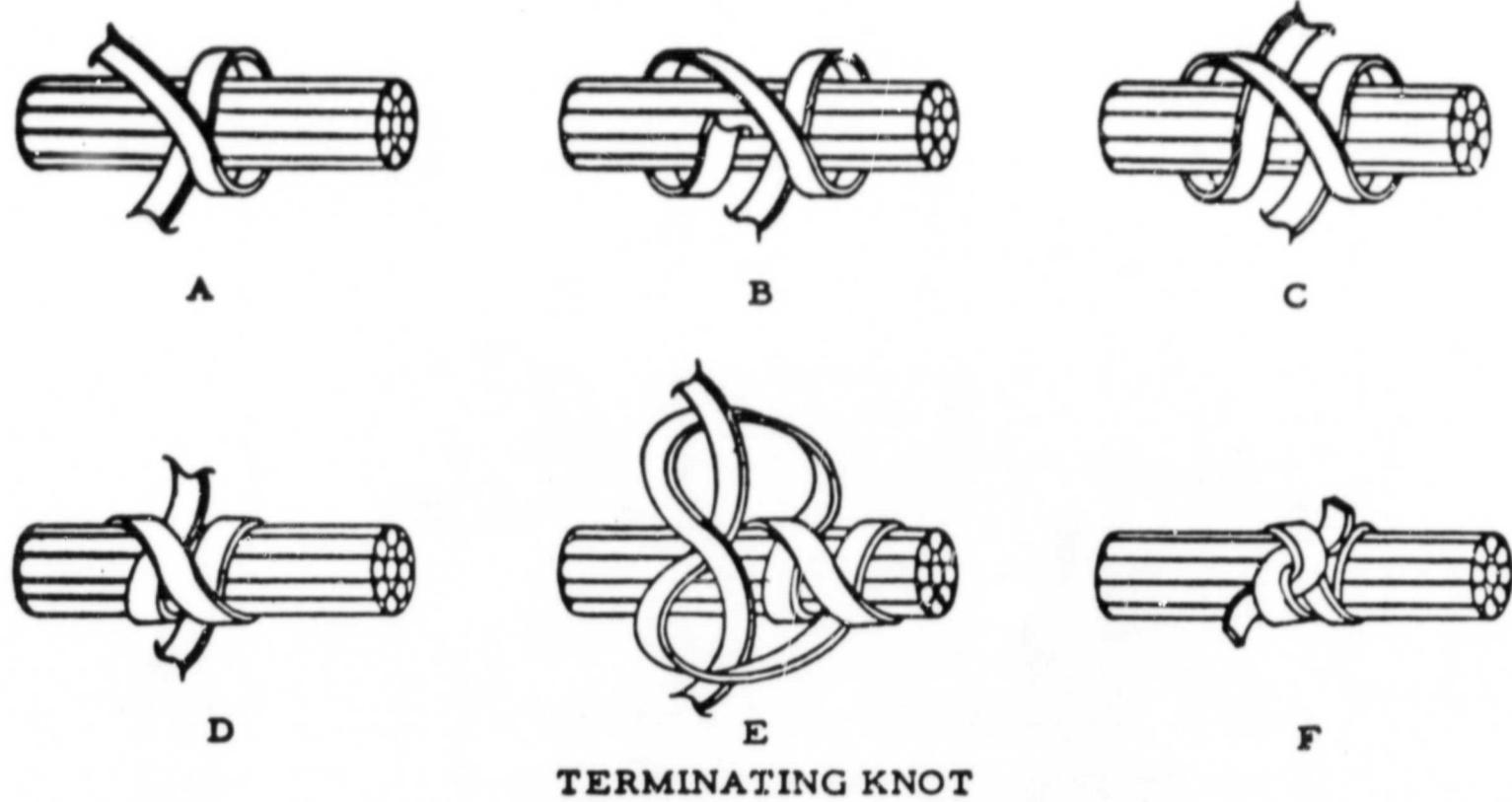
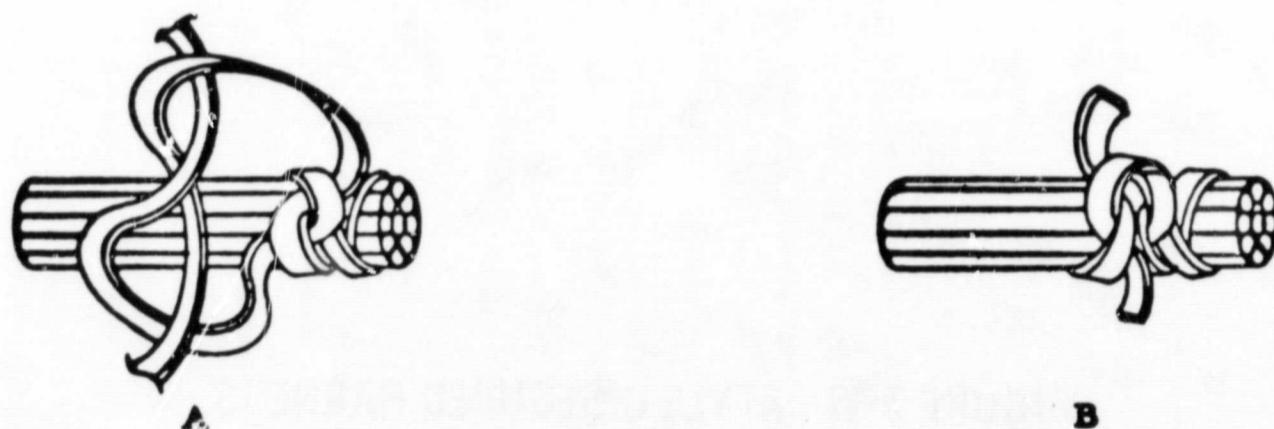


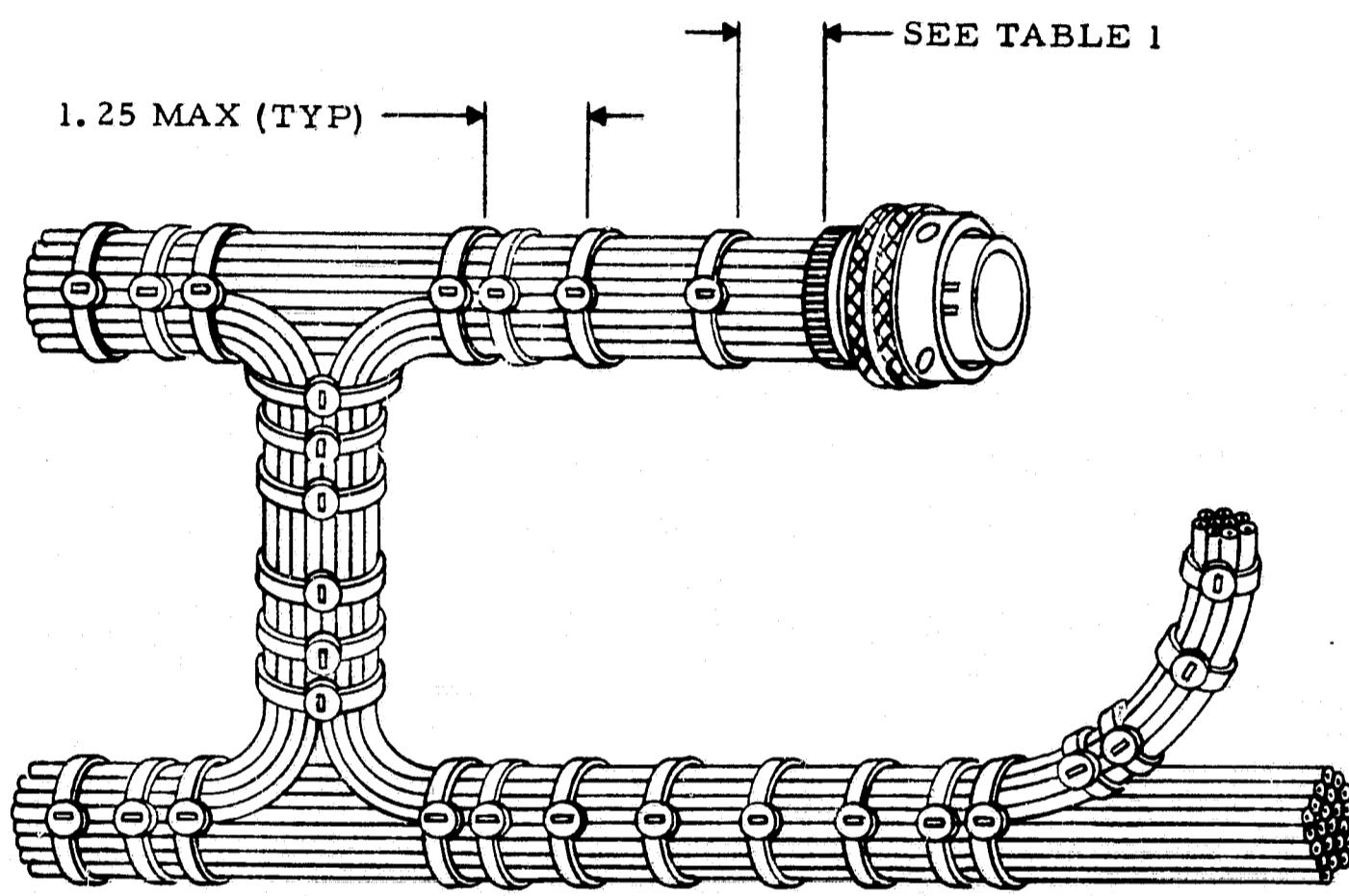
FIGURE 7-7 STYLE B SECURED HARNESS



**FIGURE 7-8 SPOT TIE**



**FIGURE 7-9 SQUARE KNOT**



**FIGURE 7-10    STYLE C SECURED HARNESS**

## SECTION 8

### STRIPPING ELECTRICAL WIRE AND CABLE

#### 8.1 GENERAL

The intent of this section is to establish techniques for the removal of insulation from electrical wire and cable. Several types of thermal and mechanical wire stripping equipment are available in both manual and automatic modes, but only the acceptable manual methods shall be covered in this section. Regardless of the method used, automatic or manual, it is essential that the stripped wire or cable meet the requirements contained in the following paragraphs.

#### 8.2 PROCESS CONTROL REQUIREMENTS

Prior to the stripping of the electrical wire and/or cable, verify that all conductors have been cut to the required length and that wire and cable insulation is free of nicks, cuts, or abrasions. When layout operations precede stripping operations, the wires and cables shall be cut to the appropriate length necessary to preclude excessive wire or cable when collectively terminated. Assure that the harness layout is in the correct configuration and all wires and cables are free of kinks, excessive bends, etc. Verify that shrinkable sleeving has been installed where applicable and that the layout operations were successfully completed.

##### 8.2.1 GENERAL PROCESS ACCEPTANCE CRITERIA

All methods that are used in stripping wires or cables shall be in accordance with applicable standards and specifications. The stripping operations shall be performed in such a manner that the conductor strands are not severed or nicked. Minor longitudinal scratches and circumferential nicks on the conductors shall be acceptable providing such scratches and nicks do not penetrate through the plating. Wire stripping tools must not cut, extrude, or otherwise damage the remaining insulation, but slight dents or impressions left by the tool are acceptable. Frayed insulation at stripped wire ends is unacceptable, although a few fibrous threads may be allowed to remain providing they do not interfere or represent more than 10%

8.2.1 GENERAL PROCESS ACCEPTANCE CRITERIA (Continued)  
of the total fiber stranding.

8.2.2 METHOD SELECTION

Thermal wire stripping tools shall be used, whenever possible, to remove insulation from all types and sizes of wire. Non-adjustable, factory-set, cutting type, mechanical strippers shall be used when thermal strippers cannot be used. In the case of large wires or cables for which a conventional stripper does not exist, a knife may be used to remove the outer insulation.

8.2.3 TOOL APPROVAL AND HANDLING

- a. Assure that stripping tools are periodically certified. A sticker or other device shall be attached to each tool indicating that the tool has been certified, and indicating the next recertification due date. The lack of a certification sticker or symbol on a tool indicates it is not approved for use under this specification.
- b. Assure that during transportation and storage each tool is provided protection from mechanical damage.
- c. While in use, the tools should be arranged within easy reach of the operator and each tool kept in a specified place. Only those tools required for the current series of operations should be at the operator's position.
- d. In cases where a knife is used to remove the insulation material, special care shall be used in handling and storage of the knife to preclude personnel injury and/or damage to the wire/cable insulation.

8.2.4 OPERATOR QUALIFICATIONS

Personnel involved in stripping insulation from wire and cable shall be trained to:

- a. Be familiar with the requirements of this document and associated documentation.
- b. Receive instructions explaining the process requirements pertaining to stripping of electrical wire and cable insulation.
- c. Be skilled in the identification and use of tools required for stripping of wire/cable insulation.

### 8.2.5 CLEANLINESS

The work area used for the preparation of wire and cable shall exhibit a clean and orderly appearance. All dirt, grease, oil, chips, and other foreign material shall be removed from the tools, equipment and work areas.

## 8.3 THERMAL STRIPPING

Removal of wire or cable insulation utilizing the thermal stripping method shall be accomplished in accordance with the following paragraphs.

### 8.3.1 EQUIPMENT REQUIREMENTS

Thermal strippers (Figure 2) shall be thermostatically controlled with adjustable temperature of the heating elements. The heating element of the stripper should be cleaned frequently to remove melted or burned insulation. Care should be taken to eliminate burned insulation residue which may impair solderability. Ventilation should be provided where thermal strippers are used, because of the toxic fumes given off from the insulation (i.e., Teflon). Selected thermal type insulation strippers shall be capable of meeting the following requirements:

- a. Variable heat controls shall function throughout the entire range.
- b. Opposing elements shall be in direct alignment.
- c. Elements shall be free from burrs, nicks, and charred insulation.
- d. Cases of metallic bodies (other than elements) shall be at ground potential during operating condition.
- e. Wire strands shall be clean with no evidence of plastic film deposit resulting from the stripping operation.
- f. The wire insulation shall not be charred or burnt, no strings of melted insulation is allowed. A slight discoloration or gray smoked appearance is permissible. (Reference Figure 3.)
- g. The stripped wire strands shall be per Figure 3.

### 8.3.2 THERMAL STRIPPING PROCEDURE

The variable control that regulates the thermal stripper element temperature shall be adjusted so that the elements melt through the insulation without excessive discoloration of the insulation. Sever the insulation by gripping the wire or cable between the elements and rotating either the wire/cable or the tool. Heating elements should not be used to remove the severed section of insulation. If the thermal strippers incorporate

### 8.3.2 THERMAL STRIPPING PROCEDURE (Continued)

insulation gripping jaws, the jaws may be used to remove the insulation, otherwise, the insulation shall be removed by gripping the section of insulation between the thumb and finger and pulling with a twisting motion in the direction of the normal lay of the wire strands.

### 8.4 MECHANICAL STRIPPING

Hand or machine precision cutting-type strippers shall be used to strip fibrous insulation and other insulation that cannot be removed by thermal strippers. Cutting type strippers which permit operator adjustment shall not be used; only non-adjustable, factory-set, cutting strippers, hand or automatic types, shall be used for mechanical stripping. (Reference Figure 1.) When using strippers with multiple stripping holes, for long production runs on single wire sizes, unused holes in multiple dies should be blocked off to prevent accidental use of an undersize hole. When available, tools equipped with single hole dies are recommended.

#### 8.4.1 TOOL REQUIREMENTS

Mechanical wire stripping tools utilized to remove non-metallic insulation from wires or cables shall satisfy the following requirements:

- a. The conductor strands of wire shall not be nicked, gouged, or cut, but some scraping is permissible provided the base metal is not exposed when viewed under five power magnification. (Reference Figure 4.)
- b. The wire insulation shall not be punctured, crushed, or otherwise damaged to such an extent that it does not pass the dielectric acceptance requirements.
- c. The ends shall be cut square and clean except for a few remaining fibrous strands. Frequent amounts of remaining fibrous strands within the 10% allowable requirement shall not be acceptable. (Reference Figure 5.)
- d. Stripping of shielded and jacketed cable shall not nick or cut shield strands during removal of jacket insulation. Removal of shielding shall not cause damage to the primary insulation. Irregular trimming and partial combing-out of the shield strands is not acceptable. (Reference Figure 6.)

## TOOL CONTROL

The setting of the mechanical wire stripper and the work produced shall be checked to assure that no nicks or cuts appear on the metallic conductor. Stripping and stripping efficiency shall be maintained by replacing blades and calibrating when necessary. An approved periodic maintenance and calibration schedule shall be instituted whereby stripping tools will be certified.

## STRIPPING LARGE WIRES AND SHIELDED CABLES

When wire size, insulation material, or cable construction prohibits the use of standard thermal or mechanical strippers, the insulation shall be stripped with a sharp knife as illustrated (preferably an adjustable type) in Figures 7 and 8. Wires and cables stripped with a knife must satisfy the quality requirements as those stripped with conventional strippers.

## STRIPPING COAXIAL CABLES

Stripping of coaxial cable outer insulation jackets, internal insulations, and braided shielding shall be accomplished to the dimensions prescribed in the connector manufacturer's assembly instructions, when instructions are otherwise specified on the design drawing. Stripping methods shall be in accordance with paragraphs 8.3, 8.4, or 8.5, as applicable.

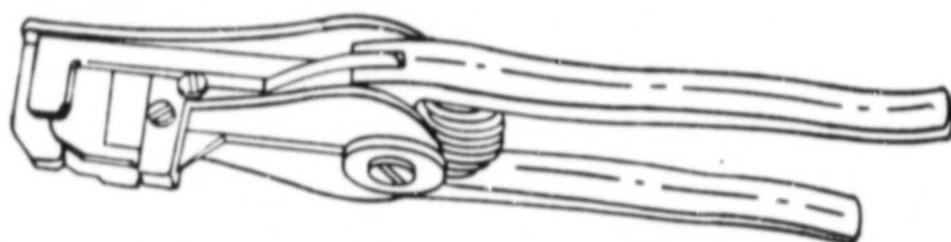


FIGURE 8-1 MECHANICAL STRIPPER

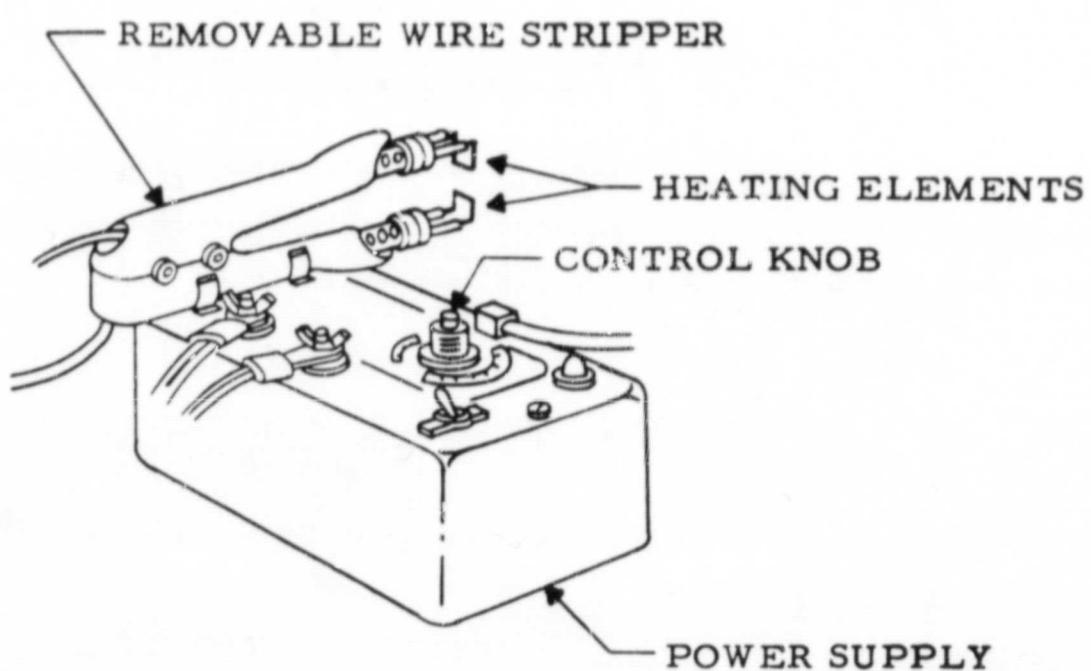
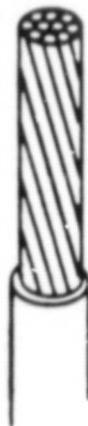


FIGURE 8-2 THERMAL STRIPPER



INSULATION STRIPPED BY THERMAL METHODS SHALL HAVE A MINIMUM OF EDGE FLASH WITH NO DAMAGE TO THE CONDUCTOR, AS SHOWN.



INSULATION EDGE FLASHING (ARROW) HAS NOT BEEN REMOVED FOLLOWING THERMAL STRIPPING.

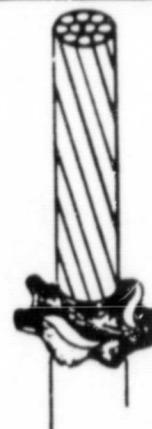
ACCEPTABLE



CONTACT WITH THERMAL STRIPPER OUTSIDE STRIPPING AREA, DURING INSULATION REMOVAL OPERATION, MAY CAUSE INSULATION DAMAGE AND EXPOSE WIRE STRANDS (ARROW).

UNACCEPTABLE

UNACCEPTABLE



BURNT OR CHARRED INSULATION, AS SHOWN, IS THE RESULT OF EXCESSIVE HEAT APPLICATION.

UNACCEPTABLE

FIGURE 8-3 THERMAL STRIPPING ACCEPTANCE CRITERIA

REPRODUCIBILITY OF THE ORIGINAL COPY IS POOR,



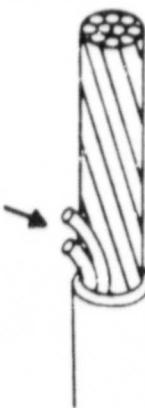
NORMAL LAY OF STRANDS,  
DISTU. BED DURING  
STRIPPING OPERATION,  
MAY BE RETWISTED TO  
THE ORIGINAL WIRE LAY,  
IF WIRES HAVE NOT BEEN  
DAMAGED.

ACCEPTABLE



WIRE STRANDS SHOW  
EVIDENCE OF A RINGED  
CONDITION CAUSED BY  
STRIPPER BLADES. OUTER  
STRANDS ARE WEAKENED  
AND MAY BREAK.

UNACCEPTABLE



SEVERAL WIRE STRANDS  
ARE CUT. THIS CONDITION  
IS DUE TO THE WRONG  
HOLE SIZE USED IN THE  
MECHANICAL STRIPPER.

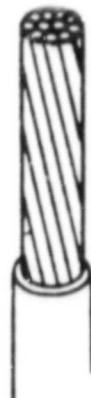
UNACCEPTABLE



WIRE STRANDS ARE NICKED,  
DUE TO MISALIGNMENT OF  
WIRE AND STRIPPING  
BLADES. NICKED STRANDS  
REVEAL BASE METAL,  
AND MAY BREAK.

UNACCEPTABLE

FIGURE 8-4 MECHANICAL STRIPPING ACCEPTANCE CRITERIA



CONDUCTOR INSULATION  
SHOULD BE REMOVED  
WITHOUT DISTURBING THE  
NORMAL LAY OF THE  
WIRE, AS SHOWN.



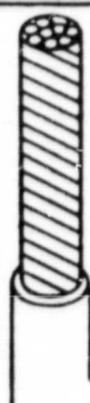
NORMAL WRAP OF WIRE  
THAT IS DISTURBED IN  
STRIPPING, AS SHOWN, IF  
RETWISTED TO ITS ORIGINAL  
WRAP, IS ACCEPTABLE.

ACCEPTABLE



STRANDS RETWISTED, AS  
SHOWN, THAT OVERLAP  
EACH OTHER WILL RESULT  
IN INCREASED STRESS AND  
DIFFICULTY IN FORMING  
A MECHANICAL WRAP.

ACCEPTABLE

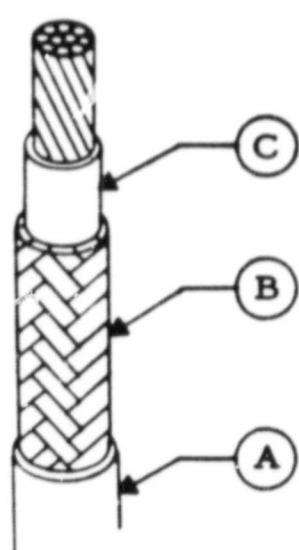


WIRES THAT ARE  
RETWISTED IN EXCESS OF  
THEIR NORMAL LAY EXERT  
INCREASED STRESS AND  
MAY BREAK.

UNACCEPTABLE

UNACCEPTABLE

FIGURE 8-5 LAY OF STRANDS



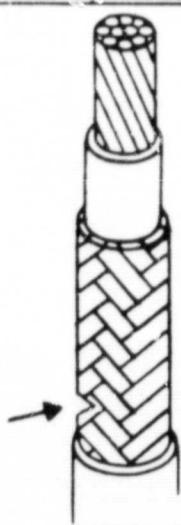
OUTER INSULATION (A) AND SHIELDING (B) HAVE BEEN PROPERLY REMOVED. NO NICKS OR CUTS ARE VISIBLE ON EITHER SHIELDING OR INNER CONDUCTOR INSULATION (C).

ACCEPTABLE



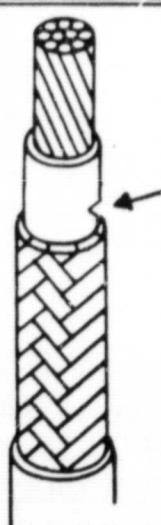
VIEW SHOWS IRREGULAR TRIMMING AND COMBING-OUT CONDITION OF SHIELDING STRANDS.

UNACCEPTABLE



VIEW SHOWS NICKED AND CUT SHIELDING STRANDS, CAUSED DURING OUTER INSULATION REMOVAL.

UNACCEPTABLE



VIEW SHOWS NICKED INNER CONDUCTOR INSULATION CAUSED DURING SHIELDING REMOVAL.

UNACCEPTABLE

FIGURE 8-6 INSULATION/SHIELDING REMOVAL

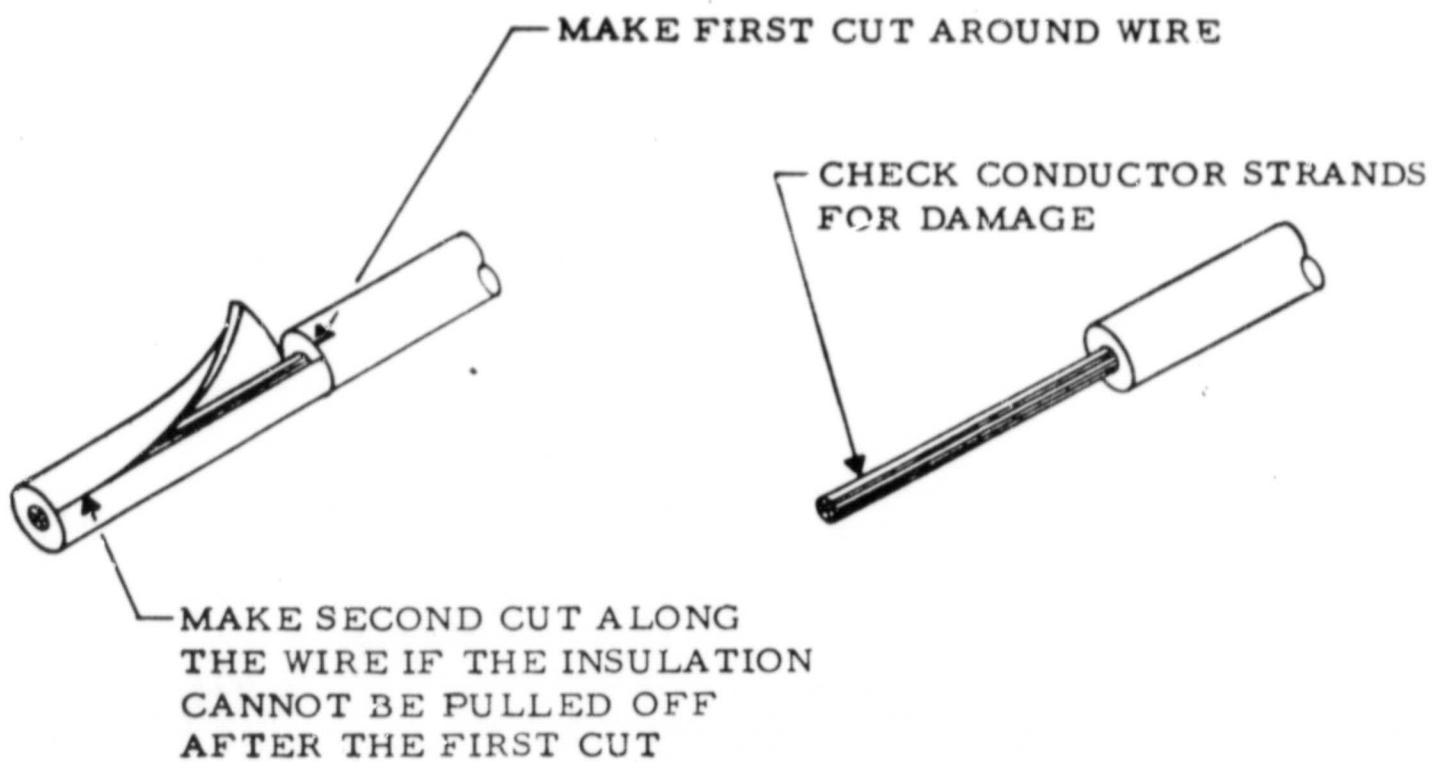


FIGURE 8-7 STRIPPING INSULATION FROM LARGE GAGE WIRES

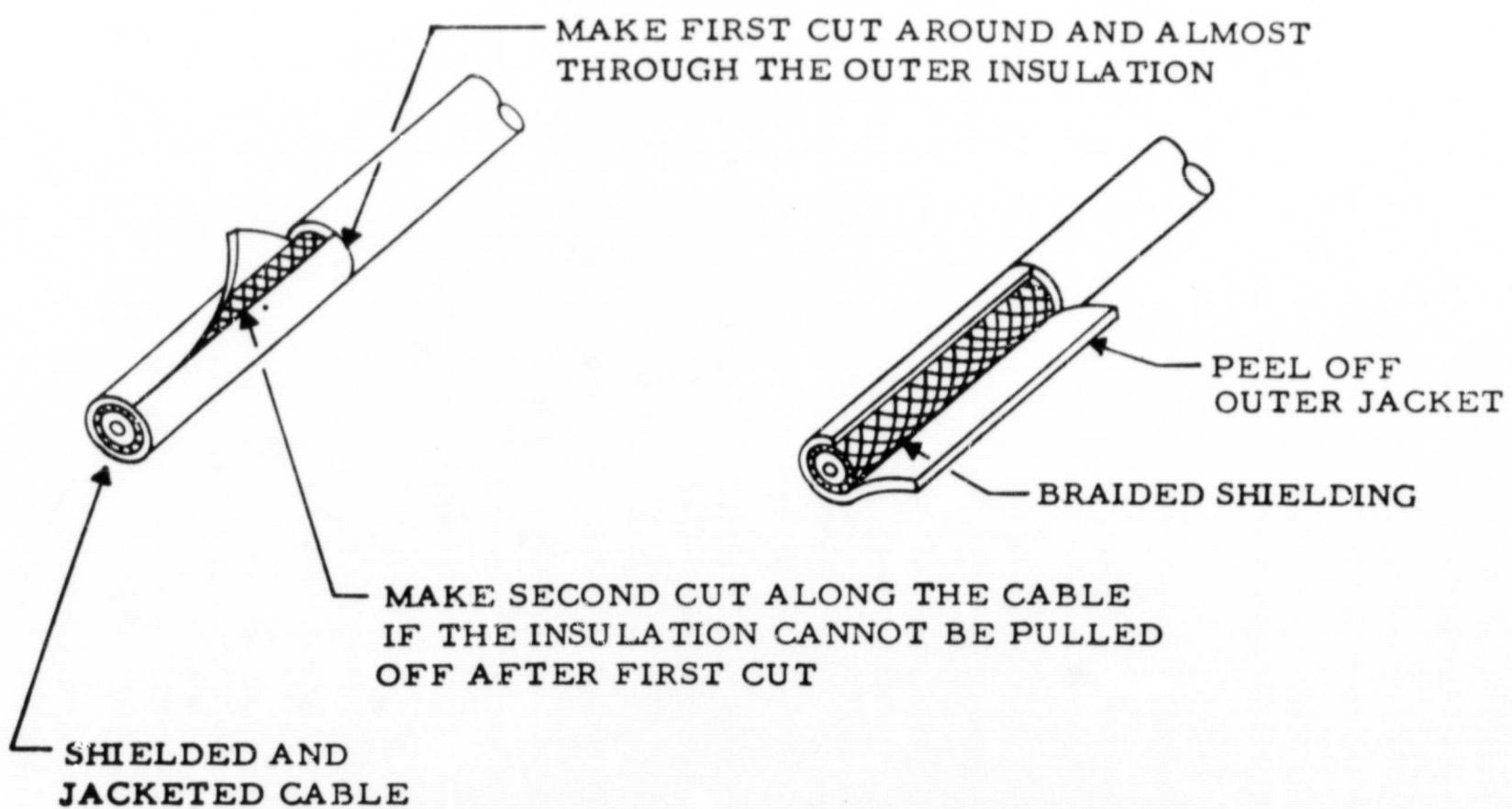


FIGURE 8-8 OUTER JACKET REMOVAL

SECTION 9  
CABLE SHIELD TERMINATION

9.1 GENERAL

When shielded cables are utilized in wire harnesses, the outer cable insulation and shield braid shall be terminated near the cable ends. The following paragraphs describe the specific methods and criteria that shall be used for termination of the cable shields.

9.2 REQUIREMENTS

When shield terminations are being made, extreme care shall be exercised in selecting the proper method, materials, and tools to assure a reliable joint. All shields that are terminated using ferrule rings shall be covered with a snug, flexible, insulating sleeve. For the purpose of this document, the term ferrule is defined as a ring used to terminate shielding. The ferrule may be of solder or crimp type and is so constructed to permit attachment of the cable shield(s) and shield return wire (if required) between the ferrule sleeves.

9.2.1 PROCESS CONTROL REQUIREMENTS

Prior to application of cable shield terminations, verify that shield braiding is not cut, nicked or scratched during removal of the cable jacket insulation. Inspect all termination hardware (i.e., rings, ferrules, insulated solder sleeves, etc.) to assure that they are of the correct type and size, and are free of tarnish, corrosion, or obvious damage. Verify that ferrule placement is properly staggered to avoid excessive harness diameter buildup and does not exceed the maximum allowable distance from the connector backshell. (Reference Figure 1.)

9.3 CLASSIFICATION AND METHODS

Shield termination of cables shall be classified as either grounded or ungrounded. Grounding of shield terminations shall be performed by means of a shield return wire. In addition, shield braid that requires terminating shall be prepared for ferrule application in accordance with any of the

### 9.3 CLASSIFICATION AND METHODS (Continued)

following methods:

- a. Two-piece crimped ferrule - braided shield
- b. Two-piece crimped ferrule - folded, combed shield
- c. Two-piece crimped ferrule - multiple shielded conductors - single folded shield
- d. Solder sleeve ferrule - nominal shield coverage
- e. Solder sleeve ferrule - maximum shield coverage

### 9.4 SHIELD TERMINATING

Shield terminations shall be in accordance with the applicable drawings, wire list, or specifications; but the following criteria shall be used as a basis for acceptable practices:

- a. Shield terminations shall be staggered in order to limit buildup of harness diameter (refer to Figure 1).
- b. Shield terminations shall not be positioned in a harness so that they occur under cable clamps or within the potted areas of electrical connectors.
- c. Shield terminations for coaxial cables shall be in accordance with the connector manufacturer's instructions, when not specified on applicable design drawings.

#### 9.4.1 INSULATION STRIPPING

When terminating a cable shield by either the grounded or ungrounded method, the cable insulation shall be stripped from the cable as specified in Section 8, "Stripping Electrical Wire and Cable". The amount of insulation removed is dependent upon the shield termination location and length of shield braid required for the ferrule assembly, if grounding is required. The removal of jacket insulation shall not cause nicks, cuts, or broken strands. There shall be no evidence of cracked, split, punctured, or damaged insulation on either the conductor(s) or jacket insulation.

#### 9.4.2 LOCATION

Cable shield terminations shall be located as indicated in Figure 1, and the following:

- a. On connectors with strain relief clamps, the measurement shall be from the back of the strain relief clamp.

#### 9.4.2 LOCATION (Continued)

- b. On connectors without strain relief clamps, the measurement shall be from the extreme back portion of the assembled connector.
- c. On potted connectors, the measurement shall be from the extreme back portion of the connector and/or potted area.

#### 9.4.3 SHIELD BRAID CUTTING

Prior to insulating an ungrounded shielded cable, or installing a ferrule set on grounded shielded cable, the braided shield must be cut at the desired location. The procedure for cutting shielded braid is illustrated in Figure 2, and shall be accomplished in accordance with the following procedure:

- a. Puff and squeeze the shield between the thumbs and forefingers of both hands and form a ring around the conductor insulation at the desired location.
- b. With a pointed tool, spread the shield strands, making a hole large enough to insert scissors.
- c. Trim the shield with a pair of scissors.

#### 9.5 TERMINATION OF FLOATING (UNGROUNDED) SHIELDED CABLES

When electrical circuit design does not require continuity of the cable shield through a connector or to ground the shielded cable shall be terminated by the floating shield method. This procedure is illustrated in Figure 3, and shall be performed by stripping the insulation to the desired length and trimming the shield braid to a length equal to one-half the cable diameter. The shield braid should then be dressed back over the end of the outer cable jacket insulation. After the shield braid has been dressed, cover the termination with insulation sleeving as indicated in paragraph 9.7.1.

#### 9.6 SHIELD RETURN WIRES

Where electrical circuit design requires continuity of the cable shield through a connector or to ground, a shield return wire shall be used. Shield return wires shall be fabricated from insulated, flexible stranded type wire with the same temperature rating as the shielded cable. When the insulated wire is to be connected to an electrical connector contact, the wire shall be as dictated by the contact to which it is being connected, otherwise, the shield return wire shall be AWG #22. Shielded return wires formed by braiding or extending the shielding braid of a cable in the form

## 9.6 SHIELD RETURN WIRES (Continued)

of pigtails shall not be used.

### 9.6.1 LENGTH OF SHIELD RETURN WIRES

The minimum length of shield return wires shall be 2 inches. The maximum length shall depend upon the staggered locations of the ferrules, but an attempt shall be made to keep the length of the shield return wire as short as possible, without causing undue tension.

### 9.6.2 ATTACHMENT OF SHIELD RETURN WIRES

The stripped and fanned end of the shield return wire shall be positioned between the shielding braid and outer ferrule and shall extend the full distance of the ferrules to approximately flush with the end of the outer ferrule. Shield return wires may be positioned at the forward or back end of the ferrules. In general, the wires shall not cause strain on the termination points and shall be tied so that they conform to the contour of the harness. Minimum bend radius of shield return wires shall be three times the wire outer diameter.

## 9.7 SHIELD TERMINATION INSULATION

Insulation sleeving shall be used to cover the ferrule set which joins a shield return wire to a shield braid or the ungrounded, floating end of a shield braid. The sleeving shall be of sufficient length and size to ensure complete insulation of the shield termination assembly as illustrated in Figure 4. Sleeving material may be heat shrinkable or non-heat shrinkable in sizes as required. Sleeving material shall withstand the same temperatures and other environmental conditions to which the cable is subjected. Standards for inspection of heat shrinkable sleeving are illustrated in Figures 5 and 6.

### 9.7.1 APPLICATION OF INSULATION SLEEVES

Heat deflectors shall be used on heat guns when there is adequate space in the area where the sleeve is being shrunk. The deflector shall be as recommended by the manufacturer of the heat gun. When using a heat gun with a deflector, locate the sleeve near the center of the deflector while applying heat. It will not be necessary to rotate the sleeve or gun since the deflector will apply heat uniformly around the sleeve. Shrinking should be performed in a well ventilated area, since toxic fumes can be given off.

#### 9.7.1 APPLICATION OF INSULATION SLEEVES (Continued)

from certain insulation materials. Teflon sleeves will change from a translucent color to clear when the sleeves have reached the temperature required for shrinking; at this time, the heat must be removed, allowing the sleeve to shrink and return to its original color. All other types of material will shrink as the heat is applied. When a heat gun without a deflector is used to shrink sleeves, the heat gun or the sleeve must be manipulated to assure that heat is applied uniformly in order to correctly shrink the sleeve. It is preferable to use a deflector on heat guns since a shorter shrinkage time is required and the shrinkage of the sleeve will be more uniform. Heat shrinkable sleeves will shrink when the approximate temperatures listed below are reached:

<u>SLEEVING MATERIAL</u>	<u>SHRINK TEMPERATURE</u>
Teflon (TFE)	621°F
Teflon (FEP)	350°F
Kynar	350°F
Silicone Rubber	350°F

#### 9.8 GROUNDED SHIELD TERMINATION METHODS

All shielded cables that require electrical conductivity of the shield by means of shield return wire shall be terminated with the application of crimped ferrules or solder sleeve ferrules. The following criteria shall be used as a basis for selecting the termination method:

- a. Single conductor shielded cables and multi-conductor cables with individually shielded conductors (with plain or shielded outer covering), which require individual shield return wires, shall be terminated using the braided shield method with crimped ferrules, or solder sleeve ferrules (nominal or maximum shield coverage methods).
- b. The folded and combed shield termination method shall be used when the cable shielding is too tight to slide an inner ferrule between the wire conductor(s) and shield, as described in the braided shield method.
- c. When design requirements permit a common shield return for individual shielded cables within a larger cable, the single fold method of termination shall be used.

## **9.9 TWO-PIECE CRIMPED FERRULE METHODS**

Ferrule sets used for terminating grounded cable shields shall consist of a "hard" inner ferrule and a "soft" outer ferrule, to preclude damage to the inner cable insulation during crimping. Manufacturer's recommended ferrule sizes shall be selected to match the cable size and to ensure proper ferrule set assembly. Two-piece ferrules that are preassembled by the supplier may be used. Color coding dye used for ferrule size designation shall be removed prior to installation when systems contamination is a consideration factor.

### **9.9.1 CRIMPING TOOLS**

Crimping tools for ferrule sets shall be selected in accordance with the manufacturer's recommendation to ensure proper compression of each ferrule set on the shield braid. Tools shall have a valid calibration decal and crimping tool number (part number or serial number) to allow recording on the applicable permanent document, in accordance with MSC/MSFC-JD-001, "Crimping of Electrical Connections"

### **9.9.2 STANDARDS FOR CRIMPED SHIELD TERMINATION**

Crimp connections shall be inspected to determine that the shield strands are contained within the crimp area or the termination device. There shall be no sharp edges, peeled metal, cracks, burrs, or cuts on the termination ferrule after crimping. The quality of the crimped shield terminations shall be determined by a visual inspection, a maximum of 5 X magnification may be used. (Reference Figures 7, 8, 9, and 10.) Normal flow of the metallic ring, caused during the crimping operation, is acceptable.

### **9.9.3 BRAIDED SHIELD METHOD**

The braided shield method of preparing cable shields for ferrule application is illustrated in Figure 11, and shall be accomplished in accordance with the following procedure:

- a. Slide the outer ferrule over the cable.**
- b. Trim the shield braid to a length slightly in excess of the inner ferrule length.**

### 9.9.3 BRAIDED SHIELD METHOD (Continued)

- c. Flare the end of the shielding by slightly rotating the conductor(s) in a circular motion and slide the inner ferrule beneath the shield braid. When the shielding is too tight to slide the inner ferrule under, use the shield preparation method outlined in paragraph 9.9.4.
- d. Place the stripped and fanned end of the shield return wire under the outer ferrule with one stripped end contacting the shield braid directly over the inner ferrule.
- e. Slide the outer ferrule over the inner ferrule and shield return wire, crimp with the proper tool, and trim any braid or wire strands extending past the front edge of the outer ferrule.
- f. Insulate the ferrule assembly as defined in paragraph 9.7.

### 9.9.4 FOLDED AND COMBED SHIELD TERMINATION METHOD

The folded and combed shield termination method for ferrule application shall be used when cable shielding is too tight to slide an inner ferrule between the wire conductor and shield, as described in the braided shield method. Application of this procedure is illustrated in Figure 12, and shall be accomplished in accordance with the following procedure:

- a. Slide the inner ferrule over the shield braid and position it against the end of the outer cable jacket.
- b. Trim the shield braid to a sufficient length for folding back over the entire length of the inner ferrule.
- c. Comb the shield strands and fold back over the inner ferrule with the strands distributed evenly around the periphery of the ferrule.
- d. Place the stripped and fanned end of the shield return wire under the outer ferrule with one stripped end contacting the shield braid directly over the combed shield and inner ferrule.
- e. Slide the outer ferrule over the shield and shield return wire, crimp with the proper tool, and trim any braid or wire strands extending past the edge of the outer ferrule.
- f. Insulate the ferrule assembly as defined in paragraph 9.7.

#### 9.9.5 SINGLE-FOLD METHOD

The single-fold method of terminating shields for ferrule application shall be used for multi-conductor cables where each conductor is individually shielded. Application of this procedure is illustrated in Figures 13 and 14, and shall be accomplished in accordance with the following procedure:

- a. Break the cable conductors out of the shields at the required point as described in Figure 13.
- b. Slide the inner ferrule over the shield braid and position so the ends of the outer jacket insulation are located under the inner ferrule.
- c. Flatten the shield braid pigtails by hand and fold back over the inner ferrule with the pigtails evenly distributed around the periphery of the ferrule.
- d. Place the stripped and fanned end of the shield return wire under the outer ferrule with one stripped end contacting the shield pigtails directly over the inner ferrule.
- e. Slide the outer ferrule over the pigtails and shield return wire, crimp with the proper tool, and trim any pigtail braids extending past the edge of the outer ferrule.
- f. Insulate the ferrule assembly as defined in paragraph 9.7.

#### 9.9.6 TERMINATING TWO OR MORE INDIVIDUALLY TERMINATED SHIELDS TO A COMMON POINT

When the engineering drawing, wire list, or standard, specify that two or more individually terminated shields are to be joined to a common ground, interconnect the individual shield return wires as shown in Figure 15. Interconnecting shield return wires (jumpers) used in this method shall be fabricated using standard shield return wire termination methods.

#### 9.10 SOLDER SLEEVE FERRULE METHODS

Solder sleeves used for terminating grounded cable shields shall consist of a heat-shrinkable sleeve containing a preform of fluxed solder at the center and a thermoplastic sealing ring in each end (reference Figure 16). When placed over a cable shield and shield return wire (if required) and briefly heated, the sleeve shrinks and the solder and thermoplastic inserts melt, forming an insulated, encapsulated, soldered termination. Manufacturer's recommended solder sleeve sizes shall be selected to match the cable size and to ensure proper assembly.

#### 9.10.1 APPLICATION OF SOLDER SLEEVE FERRULES

Heat guns equipped with manufacturer's recommended heat reflectors shall be used for proper application of solder sleeves. The assembled unit is placed within the hot air stream of the heat gun reflector and heated as required to shrink the outer sleeve and to melt the thermoplastic inserts. Heating is continued until the solder ring changes from a dull grey color to bright silver and flows toward the dams on either end of the solder sleeve.

NOTE: Shrinking should be performed in a well ventilated area, since toxic fumes can be given off from certain insulating materials.

Just prior to the bright flow, the solder ring may collapse, but it is important that the collapse of the ring be distinguished from the actual flow of the solder, and that the unit remains in the hot air stream until the solder has actually changed color and flowed (reference Figures 17 and 18). Total heating time is dependent on the size and the type of solder sleeve and the size of the wire.

#### 9.10.2 NOMINAL SOLDER SLEEVE SHIELD COVERAGE METHOD

The nominal shield coverage method utilizing solder sleeves is illustrated in Figure 19, and shall be accomplished in accordance with the following procedure:

- a. Slide the solder sleeve over the cable.
- b. Strip the outer cable insulation at staggered locations, starting with 1.5 inches and extending up to four inches of the connector backshell.
- c. Place the stripped and fanned end of the shield return wire under the solder sleeve with the stripped end contacting the shield braid as shown in Figure 19.
- d. Apply heat to the solder sleeve as described in paragraph 9.10.1.

#### 9.10.3 MAXIMUM SOLDER SLEEVE SHIELD COVERAGE METHOD

For maximum shield coverage, the shields shall extend up to the conductor termination and floated by folding back over the conductor insulation and covered with heat shrinkable tubing as described in paragraph 9.5, and as illustrated in Figure 3. Openings shall be made in the outer cable insulation and staggered starting with 1.5 inches and extending up to four inches from the connector backshell for the installation of solder sleeves. Solder sleeves and shield return wires shall be applied as described in paragraph

9.10.3 MAXIMUM SOLDER SLEEVE SHIELD COVERAGE METHOD (Continued)

9.10.2, and as illustrated in Figure 20.

9.10.4 EXAMINATION OF COMPLETED SOLDER SLEEVE

After application of heat, visually examine the solder sleeve joint for proper heating of the solder by verifying that the solder ring has lost its original configuration and no longer has a definite width. The solder joint shall have a bright and shiny appearance with wetting of adjacent surfaces (reference Figure 21). The completed solder sleeve shall be centered on the splice or shield termination area and be free of cracks, punctures, splits, or tears. The conductor and/or shield strands shall lie flat and shall not protrude through the insulated sleeve.

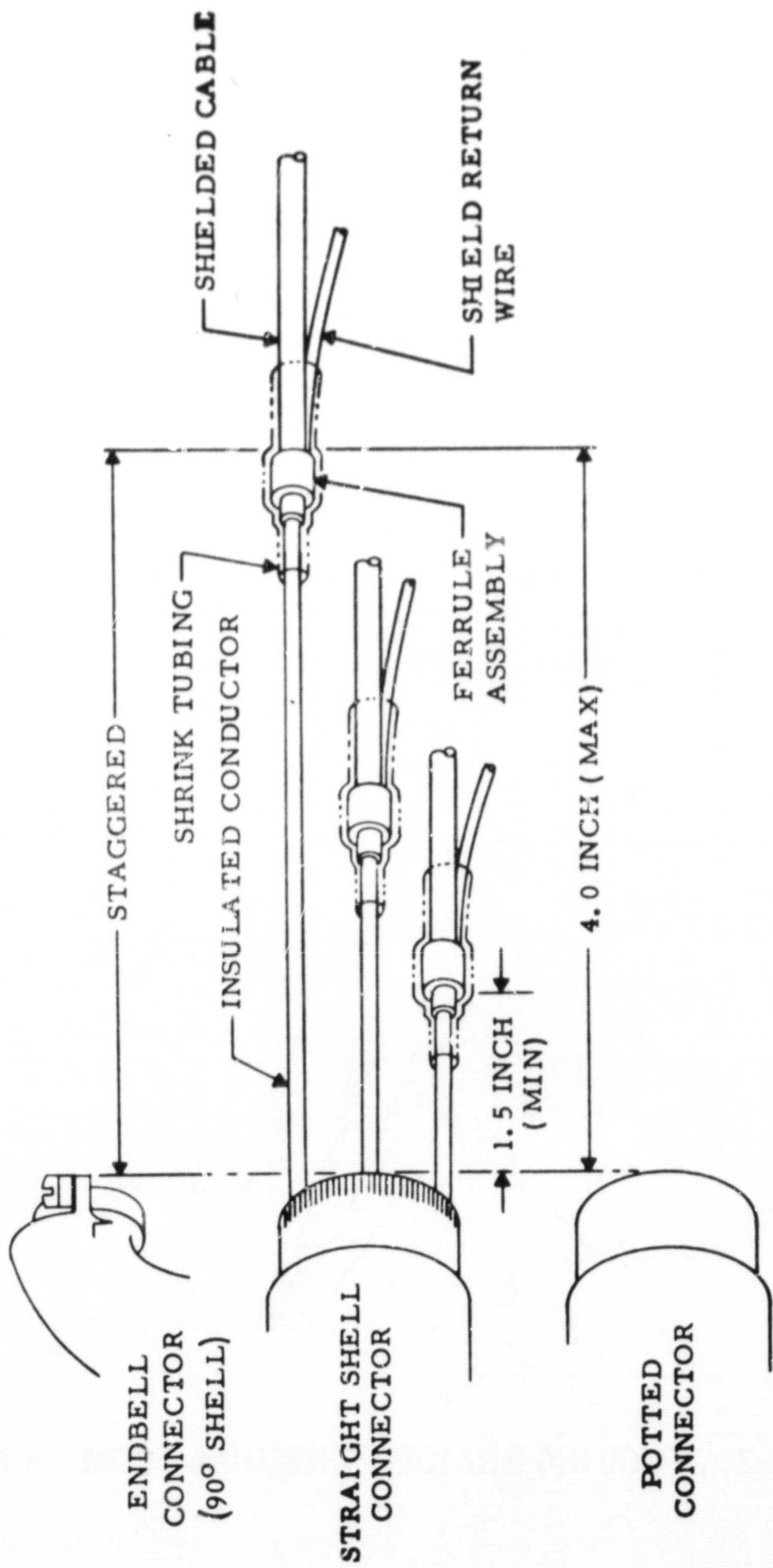


FIGURE 9-1 LOCATION OF SHIELD TERMINATIONS

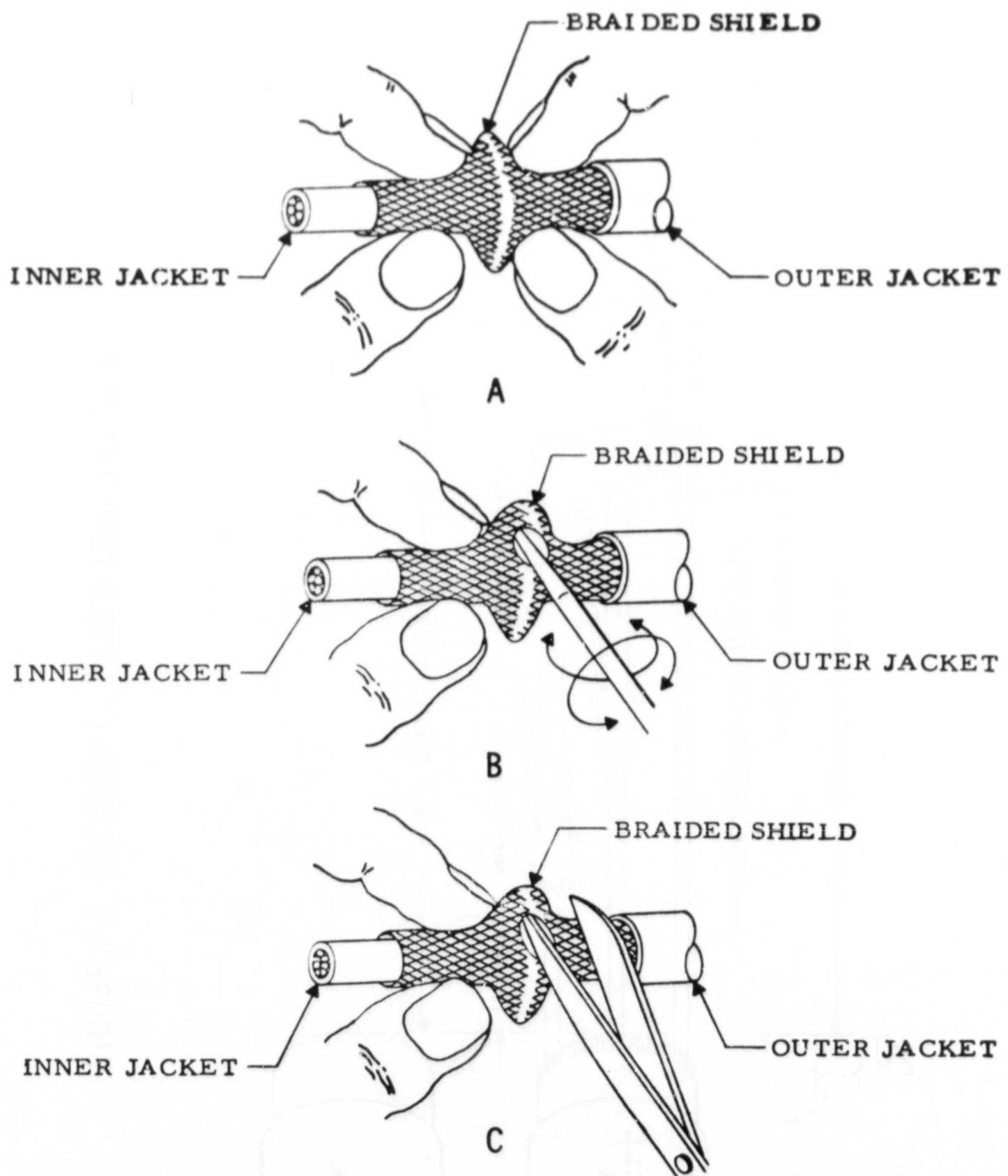
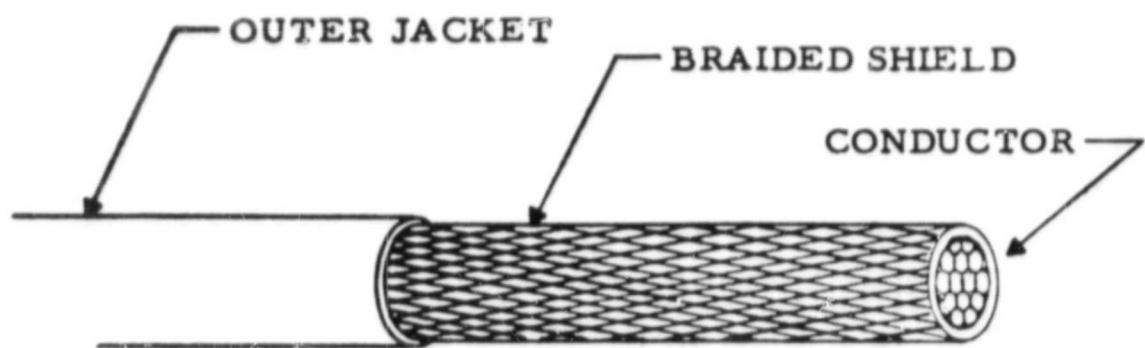
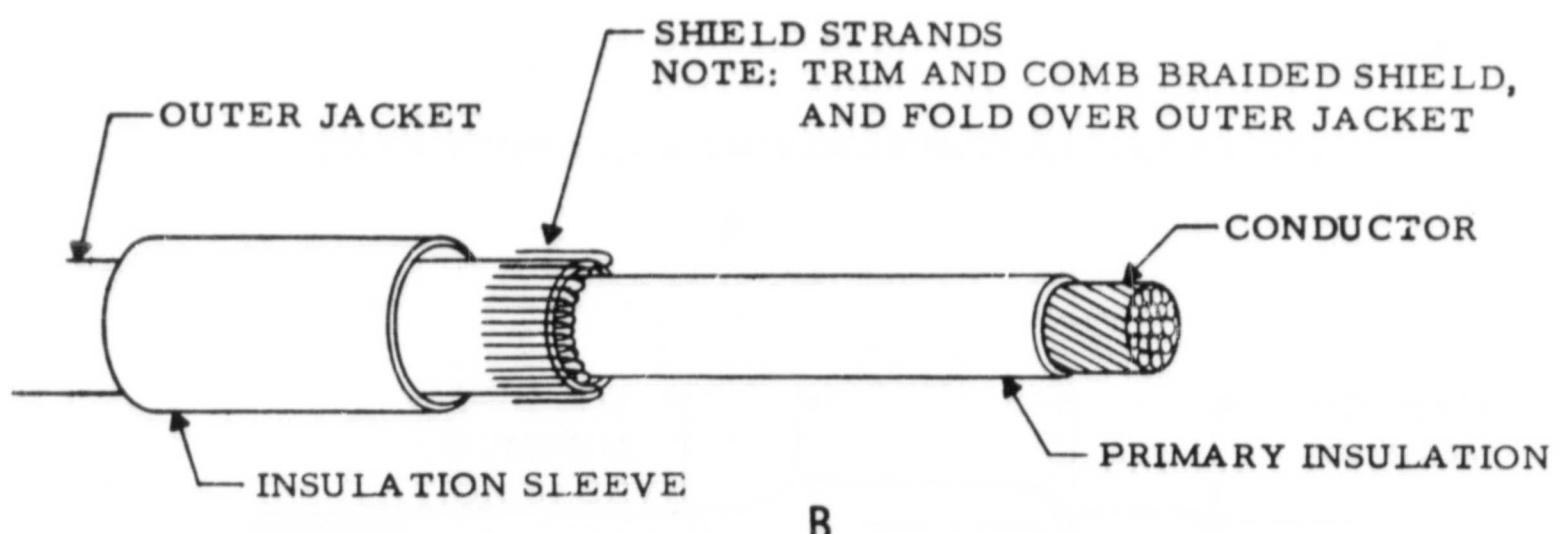


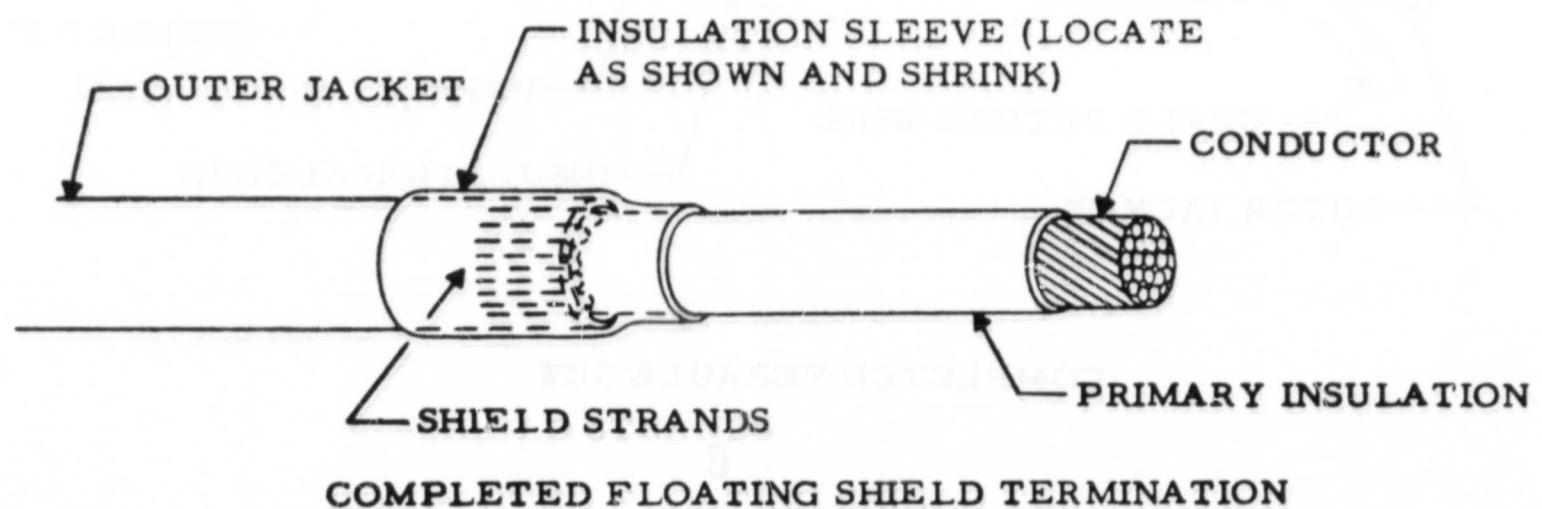
FIGURE 9-2 REMOVING BRAIDED SHIELDING FROM CABLE



A

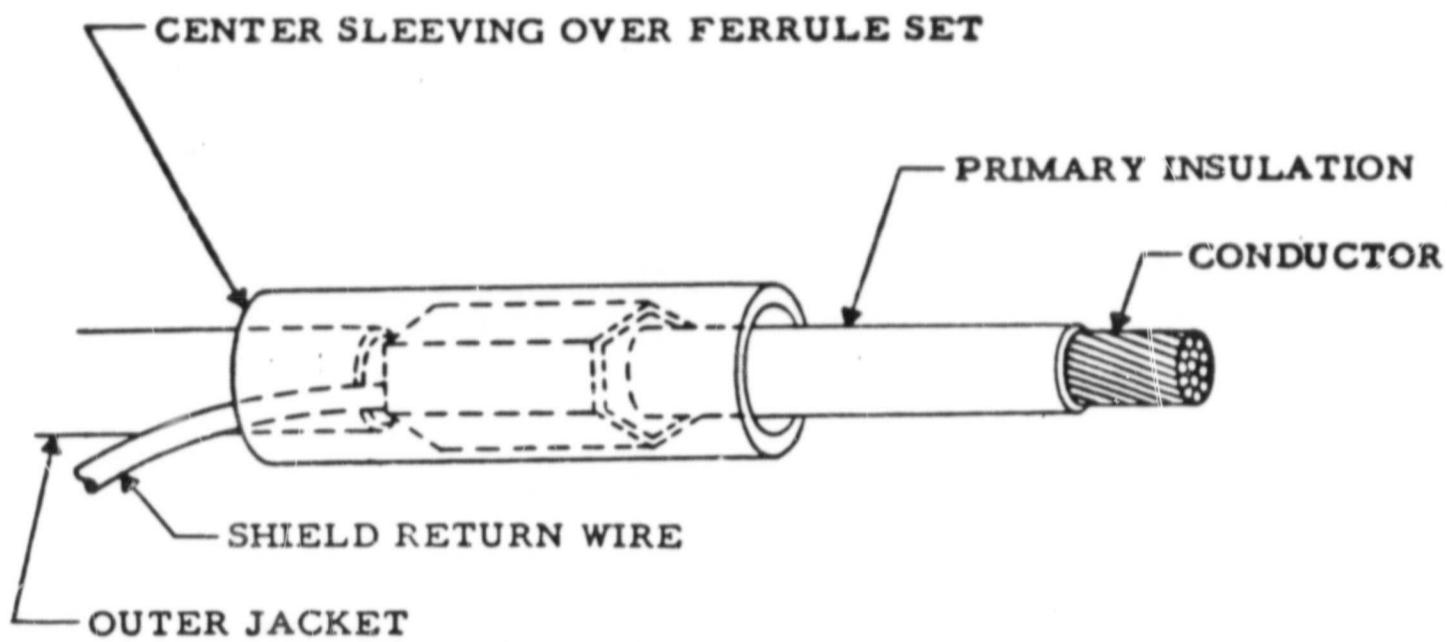


B



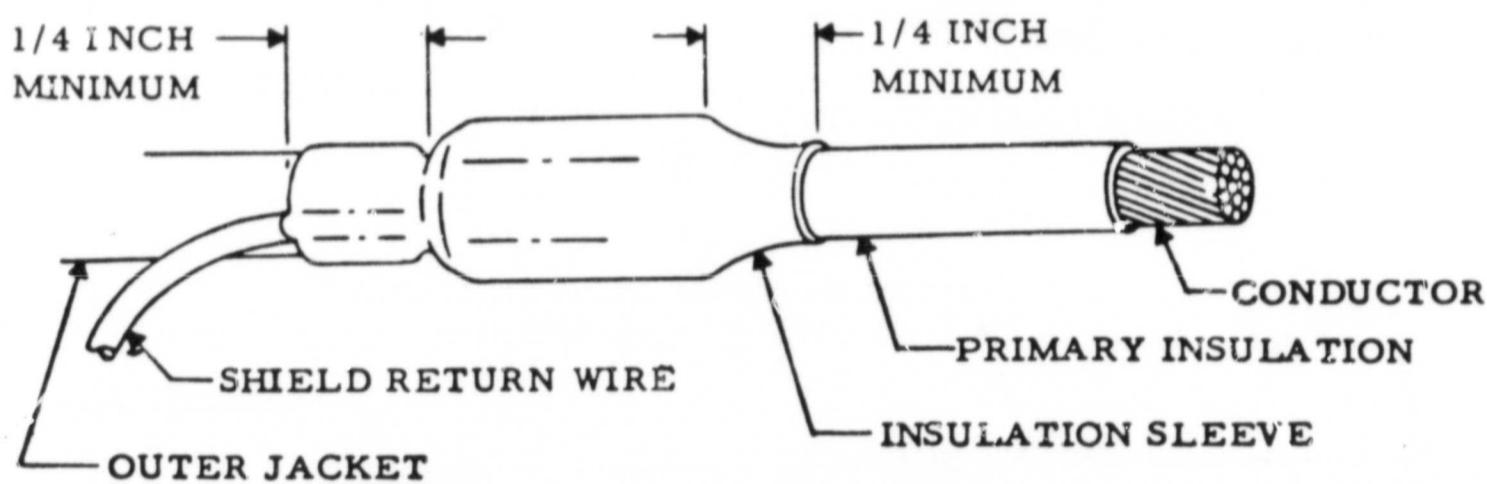
C

FIGURE 9-3 TERMINATION OF FLOATING BRAIDED SHIELD



CENTER INSULATION SLEEVING AND APPLY HEAT

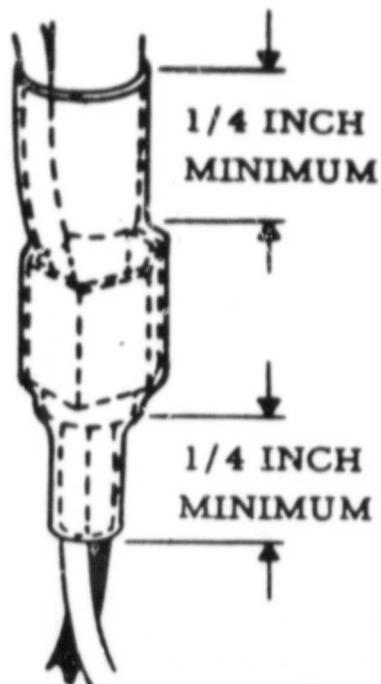
A



COMPLETED FERRULE SET

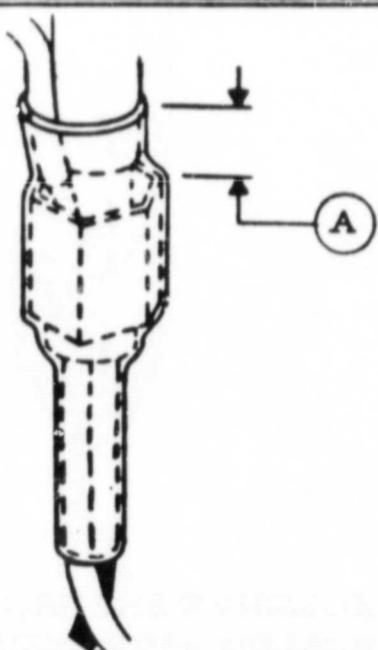
B

FIGURE 9-4 INSULATING SHIELD TERMINATIONS



SLEEVING SHALL BE CUT TO LENGTH AND SHOULD BE CENTERED OVER THE FERRULE, AS SHOWN, AFTER SHRINKING.

ACCEPTABLE



SLEEVING (A) DOES NOT EXTEND 1/4 INCH BEYOND THE FERRULE.

UNACCEPTABLE



CARELESS POSITIONING OF THE INSULATING SLEEVE (ARROW) HAS CREATED A POTENTIAL SHORT OR GROUNDING OF THE SHIELD BRAID.

UNACCEPTABLE

FIGURE 9-5 STANDARDS FOR HEAT SHRINKABLE SLEEVING



SLEEVING SHALL BE FREE OF CRACKS OR SPLITS WHEN SHRUNK. IT SHALL FIT THE AREA SNUG ENOUGH TO PREVENT ANY SLIPPING OVER THE FERRULE, AS SHOWN. IT DOES NOT REQUIRE A TIGHT SEAL.

ACCEPTABLE



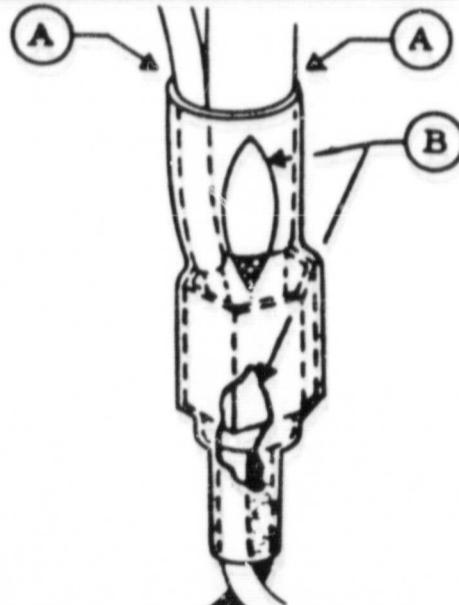
SLEEVING HAS BEEN SHRUNK JUST ENOUGH TO MAINTAIN ITS POSITION OVER THE FERRULE.

ACCEPTABLE



SLEEVING HAS NOT BEEN SHRUNK ENOUGH TO PREVENT IT FROM SLIPPING OFF THE FERRULE.

UNACCEPTABLE



EXCESSIVE SHRINKING HAS COMPRESSED WIRE INSULATION (A), AND CAUSED SEVERE SPLITTING OF SLEEVING (B). THIS IS USUALLY THE RESULT OF USING THE WRONG SIZE SLEEVE.

UNACCEPTABLE

FIGURE 9-6 STANDARDS FOR HEAT SHRINKABLE SLEEVING



THE INNER SLEEVE SHALL EXTEND PAST THE OUTER SLEEVE. EXCESS SHIELDING SHALL BE TRIMMED OFF AT THE POINT WHERE INNER SLEEVE EXTENDS PAST OUTER SLEEVE (ARROW).

ACCEPTABLE



INNER SLEEVE DOES NOT EXTEND BEYOND OUTER SLEEVE.

UNACCEPTABLE



INNER SLEEVE EXTENDS BEYOND MAXIMUM ALLOWABLE. THIS RESULTS IN A REDUCTION OF THE CONTACT SURFACE AND AN INSUFFICIENT CRIMP.

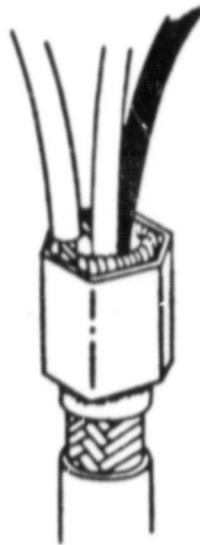
UNACCEPTABLE



FERRULE IS NOT COMPLETELY FORMED (ARROW), DUE TO IMPROPER POSITIONING IN CRIMPING TOOL.

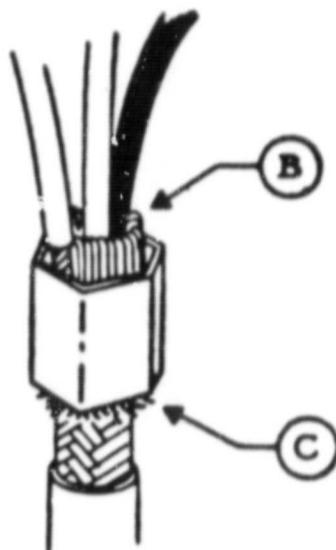
UNACCEPTABLE

FIGURE 9-7 UNGROUNDED FERRULE-UNINSULATED-TWO PIECE



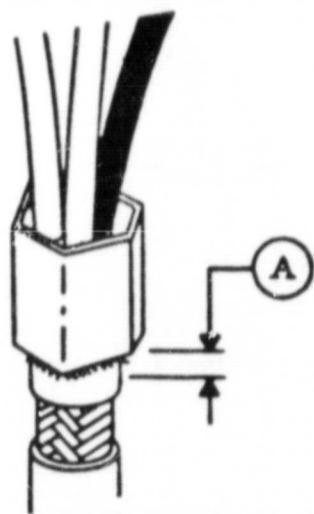
THE INNER SLEEVE SHALL EXTEND PAST THE OUTER SLEEVE. THE BRAIDED SHIELD STRANDS SHALL BE COMBED OUT, AND EVENLY SPREAD BACK OVER THE INNER SLEEVE.

ACCEPTABLE



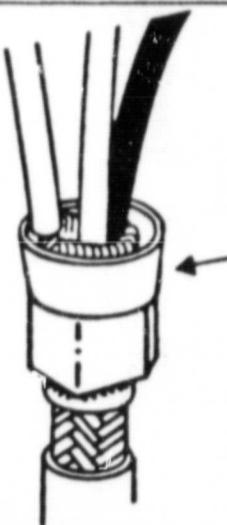
INNER SLEEVE DOES NOT EXTEND BEYOND OUTER SLEEVE. THE COMBED STRANDS (B) ARE NOT EVENLY DISTRIBUTED AROUND THE SLEEVE. SHIELDING STRANDS ARE NOT TRIMMED FLUSH WITH THE EDGE OF THE OUTER SLEEVE (C).

UNACCEPTABLE



INNER SLEEVE EXTENDS BEYOND MAXIMUM ALLOWABLE (A). THIS RESULTS IN A REDUCTION OF THE CONTACT SURFACE AND AN INSUFFICIENT CRIMP.

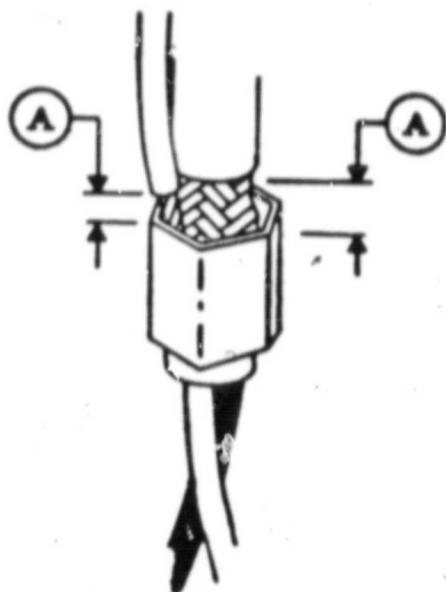
UNACCEPTABLE



FERRULE IS NOT COMPLETELY FORMED (ARROW), DUE TO IMPROPER POSITIONING IN THE CRIMPING TOOL.

UNACCEPTABLE

FIGURE 9-8 GROUNDED FERRULE-UNINSULATED TWO PIECE



THE INSULATION GAP (A) OF BOTH THE OUTER JACKET AND GROUND JUMPER WIRE, SHALL NOT BE MORE THAN  $3/16 \pm 1/16$ . THERE SHALL BE NO EVIDENCE OF NICKS, CUTS, OR ABRASION ON THE SHIELDING OR JUMPER WIRE.

**ACCEPTABLE**



THE CABLE INSULATION HAS BEEN STRIPPED TO THE MAXIMUM ALLOWABLE GAP. THERE IS NO VISIBLE SHIELDING DAMAGE.

**ACCEPTABLE**



CABLE (B) HAS BEEN INSERTED TOO FAR INTO CRIMPED CONNECTION. POSSIBLE SHIELDING WIRE DAMAGE FROM STRIPPING WOULD NOT BE VISIBLE.

**UNACCEPTABLE**



CABLE INSULATION GAP HAS EXCEEDED THE 1/4 INCH MAXIMUM ALLOWABLE DIMENSION.

**UNACCEPTABLE**

**FIGURE 9-9 JACKET INSULATION TO FERRULE REQUIREMENTS**

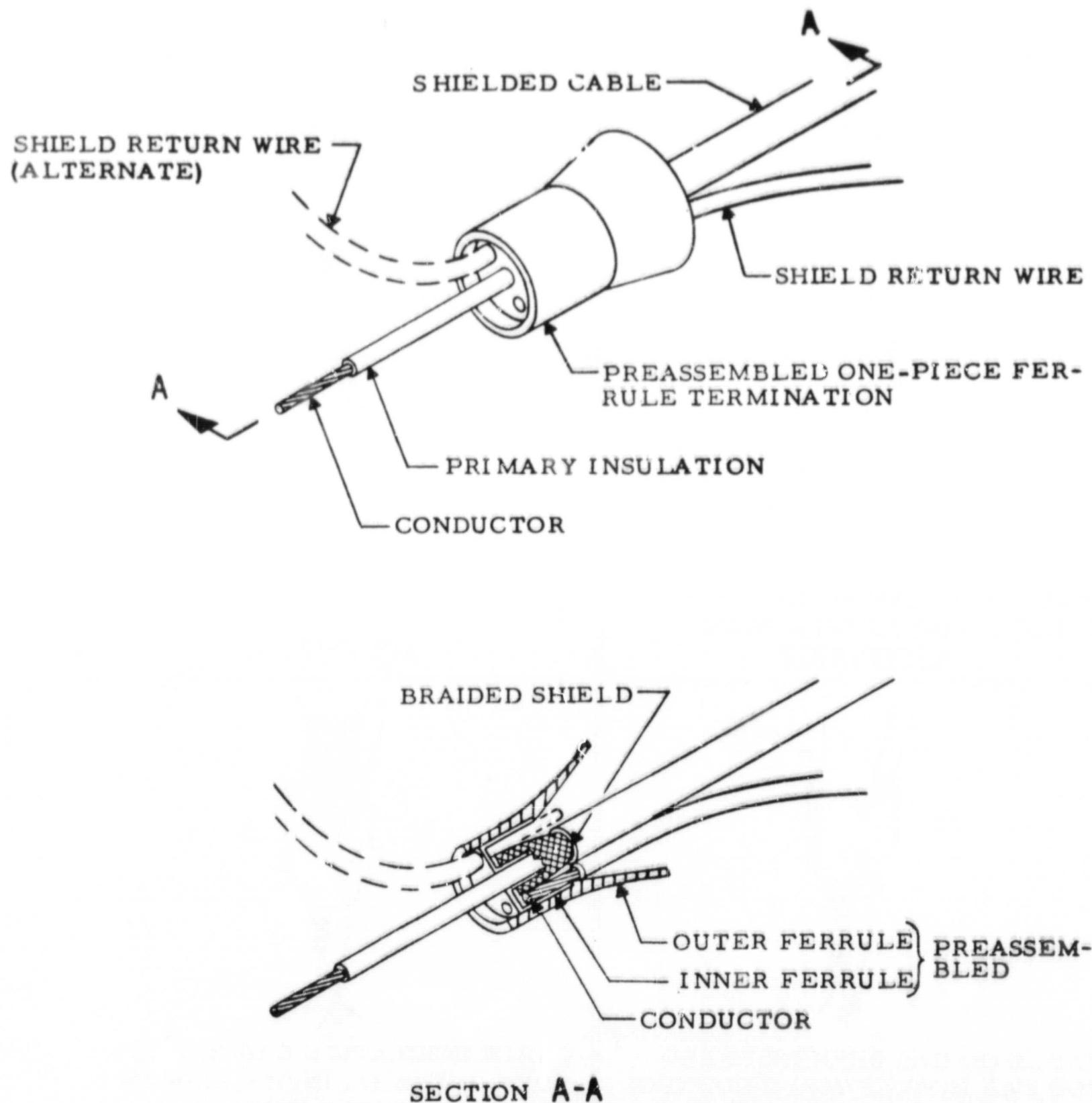
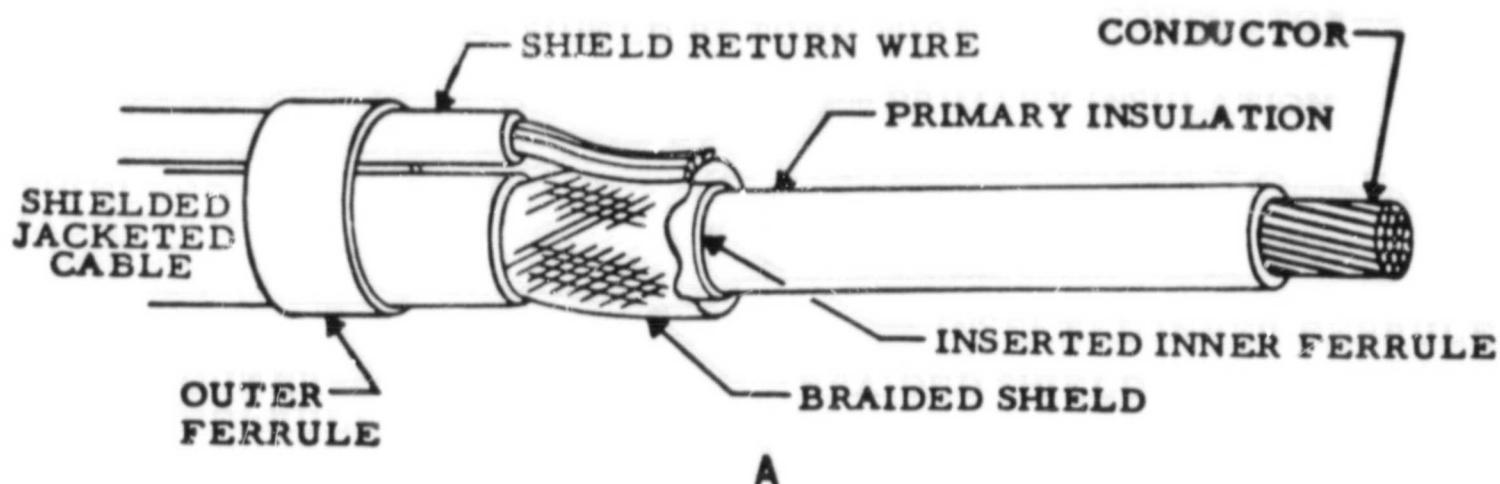
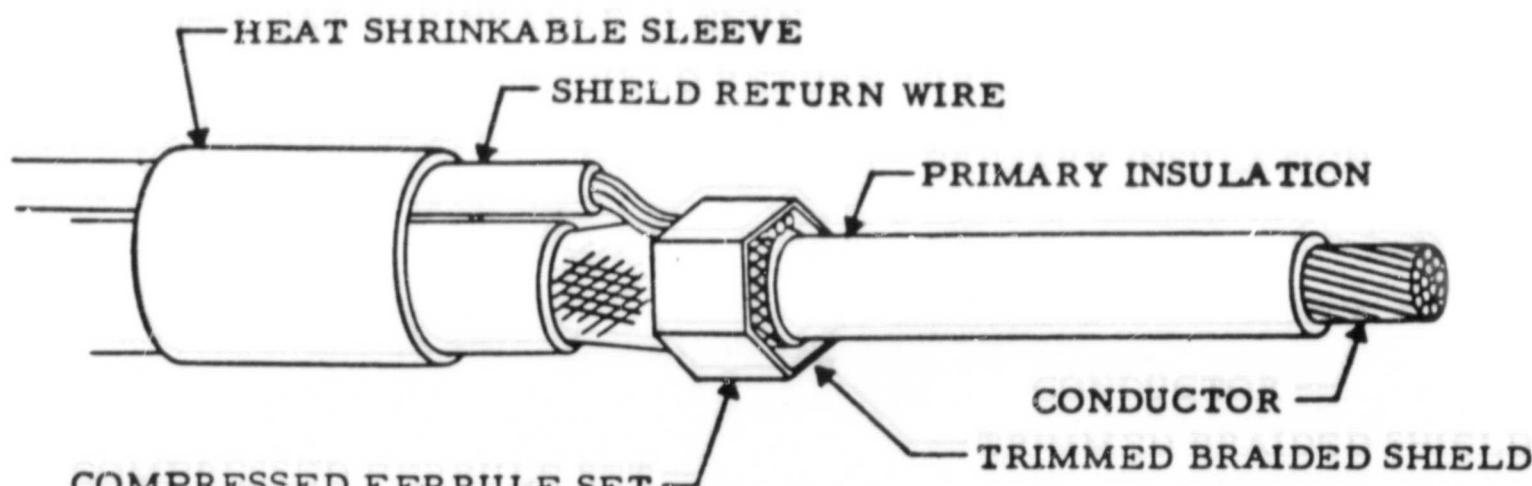


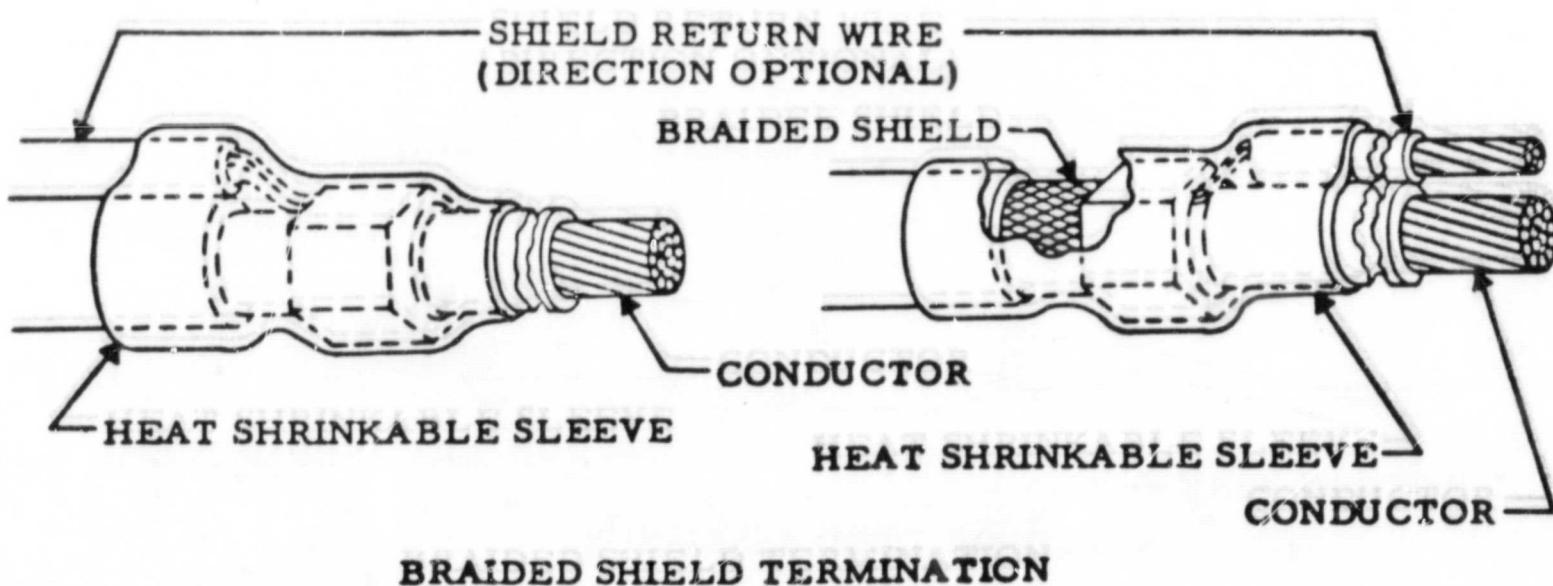
FIGURE 9-10 PREASSEMBLED ONE-PIECE FERRULE TERMINATION



A



B



C

FIGURE 9-11 STANDARD SHIELD TERMINATION

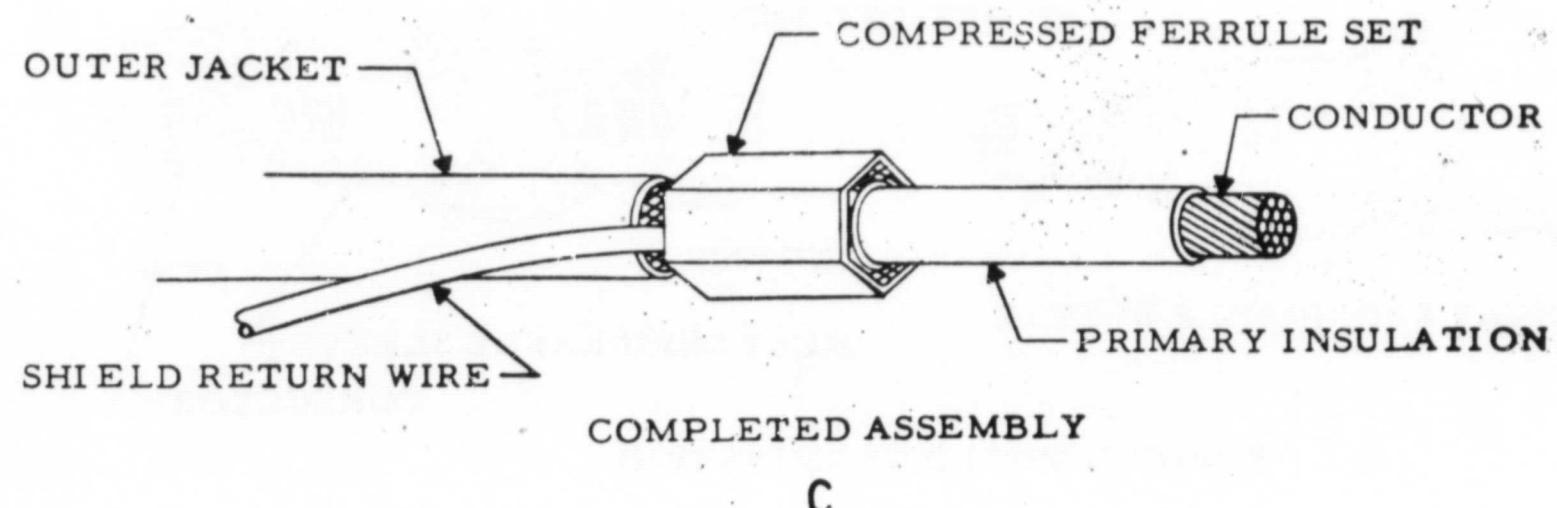
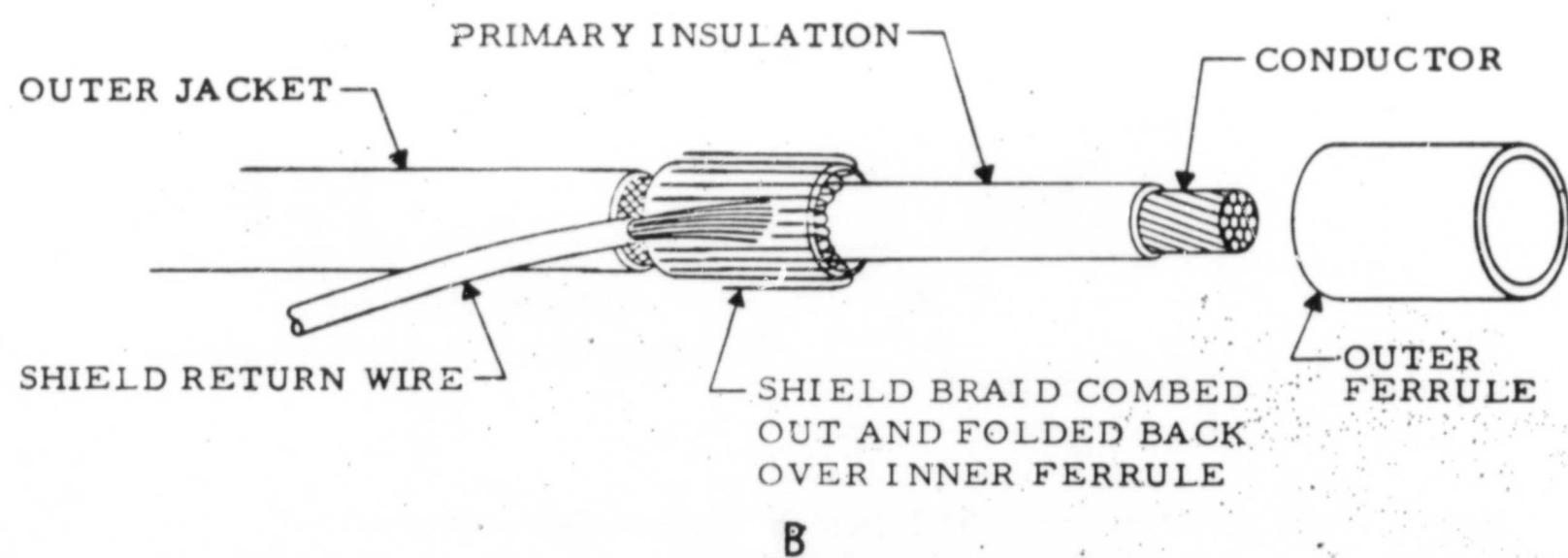
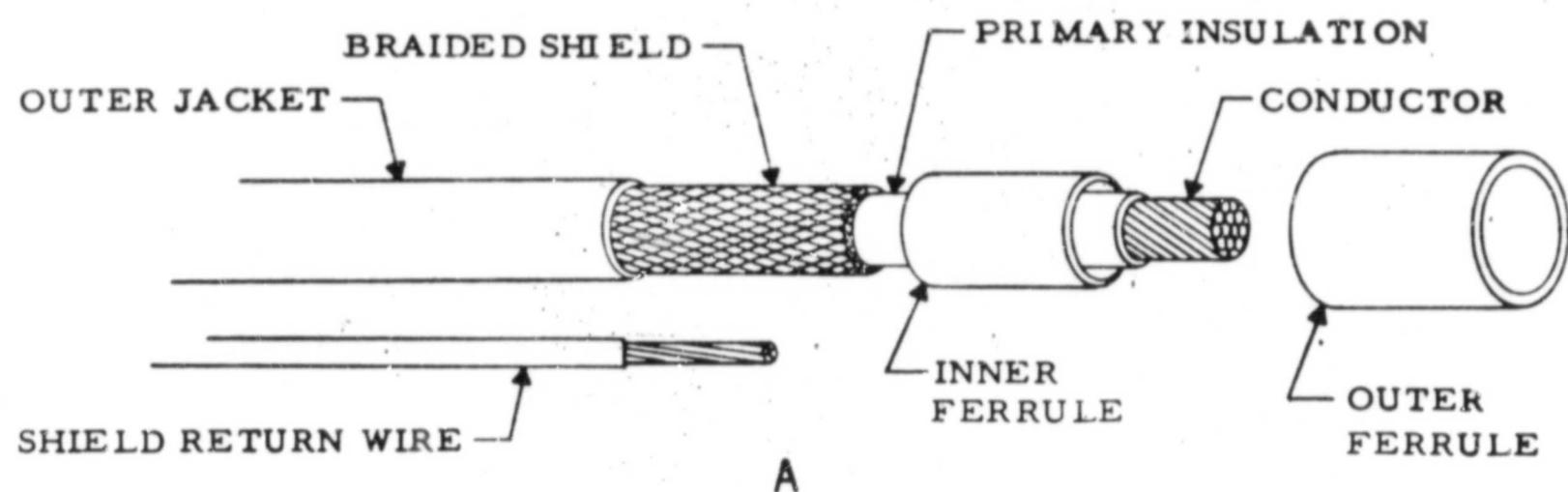


FIGURE 9-12 ALTERNATE SHIELD BRAID TERMINATION PROCEDURE

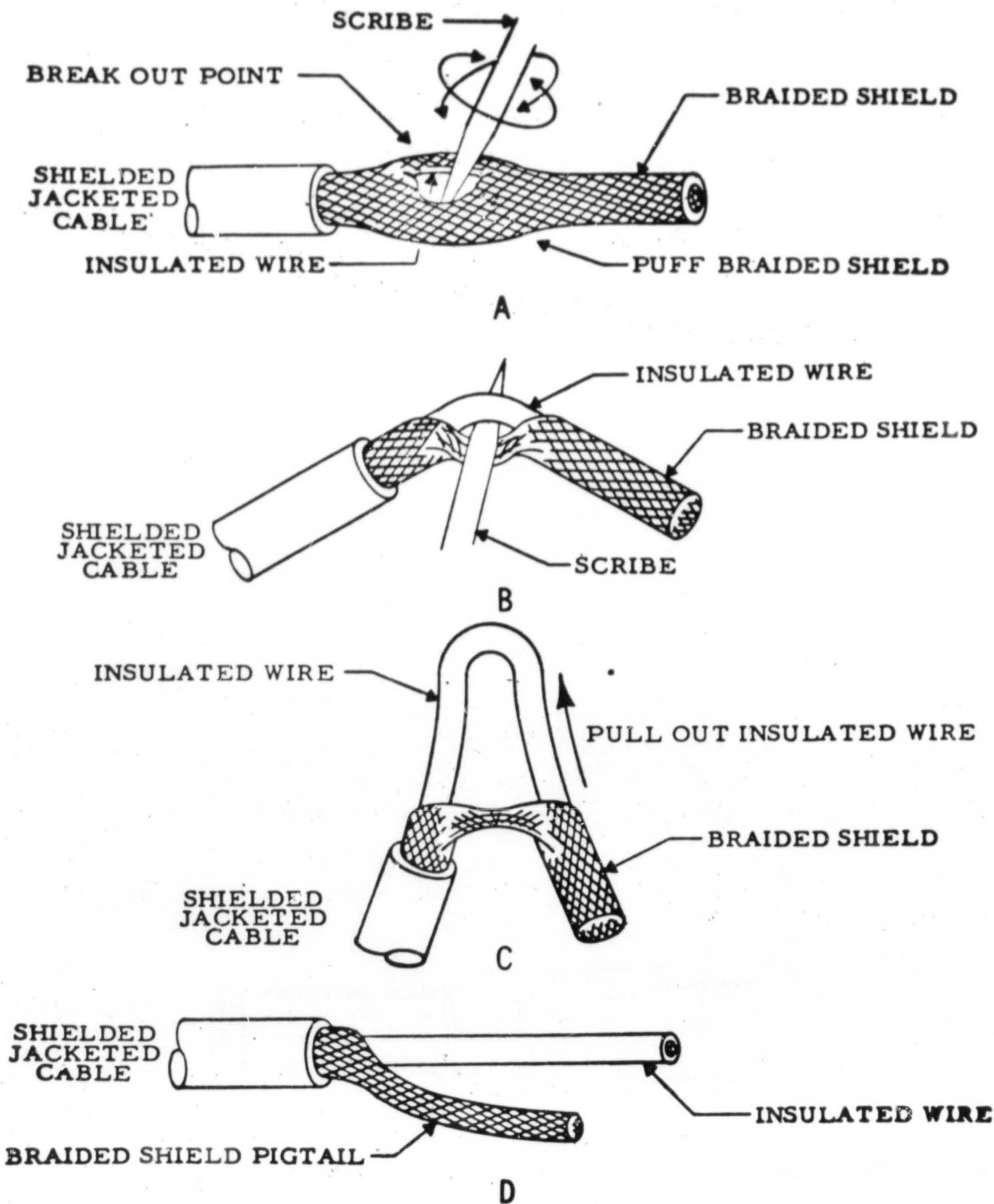


FIGURE 9-13 BREAKING OUT BRAIDED SHIELD PIGTAILS

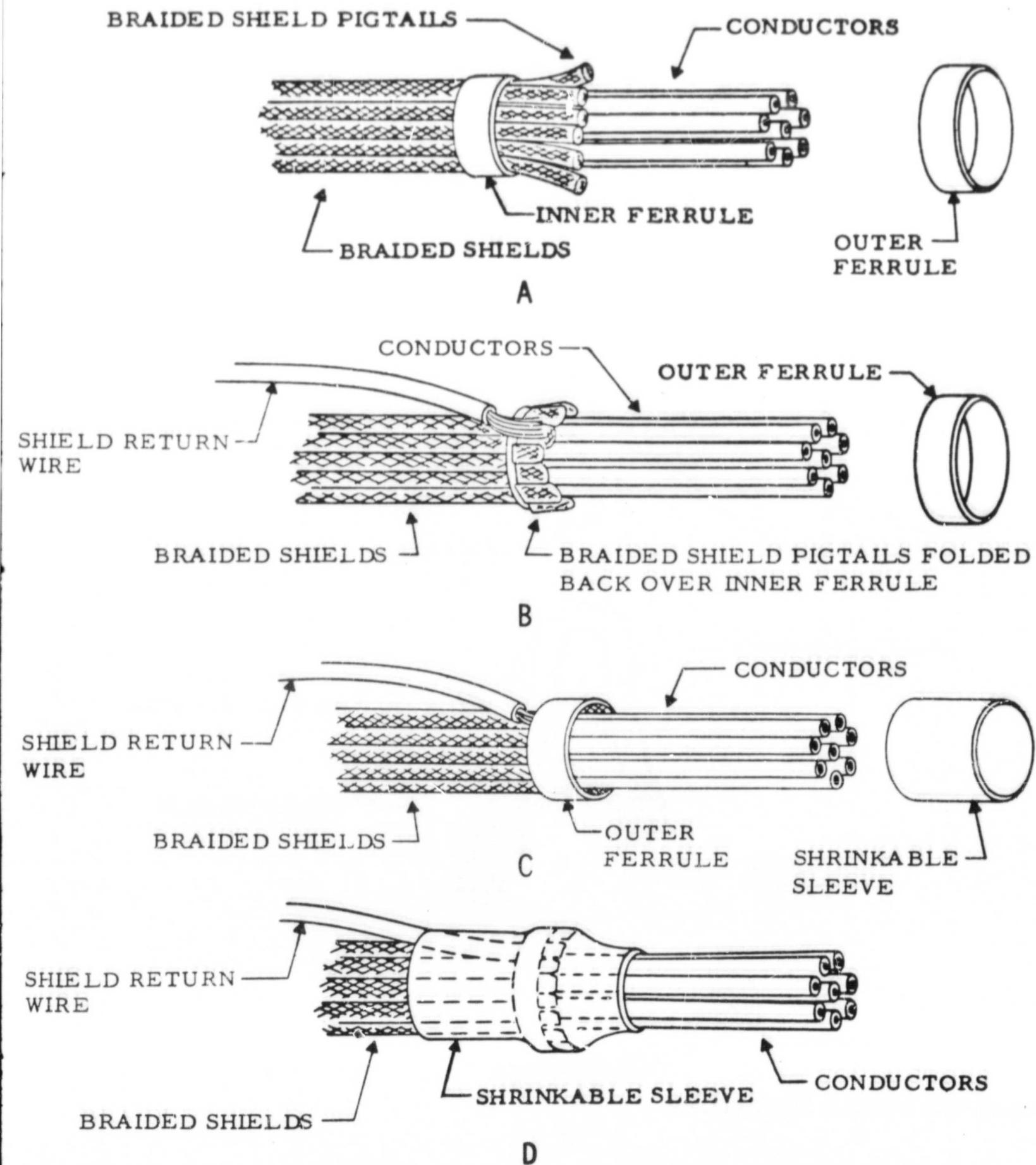


FIGURE 9-14 SHIELD TERMINATION OF MULTI-CONDUCTOR, SHIELDED CABLE

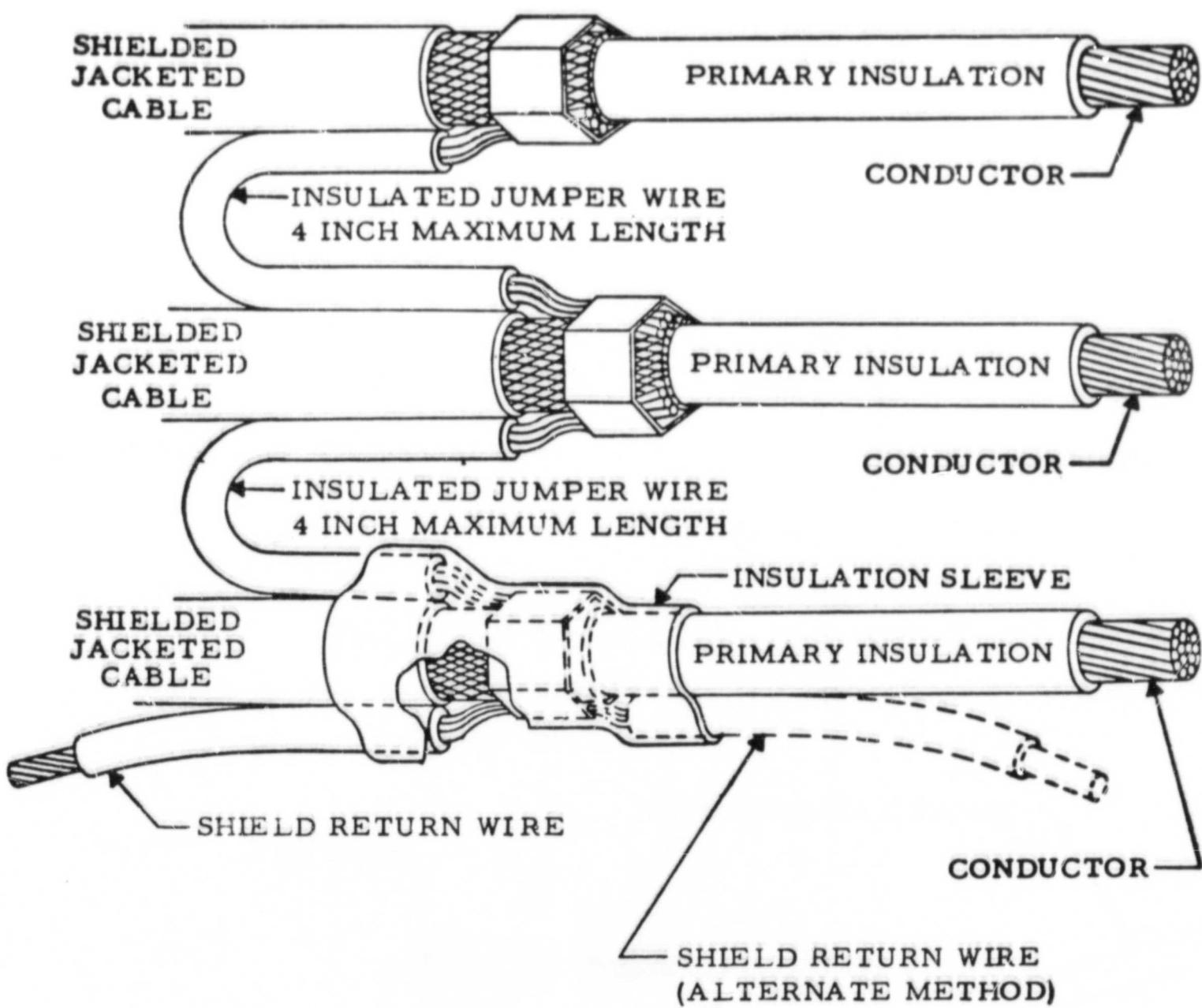


FIGURE 9-15 TERMINATING TWO OR MORE SHIELDS TO A COMMON POINT

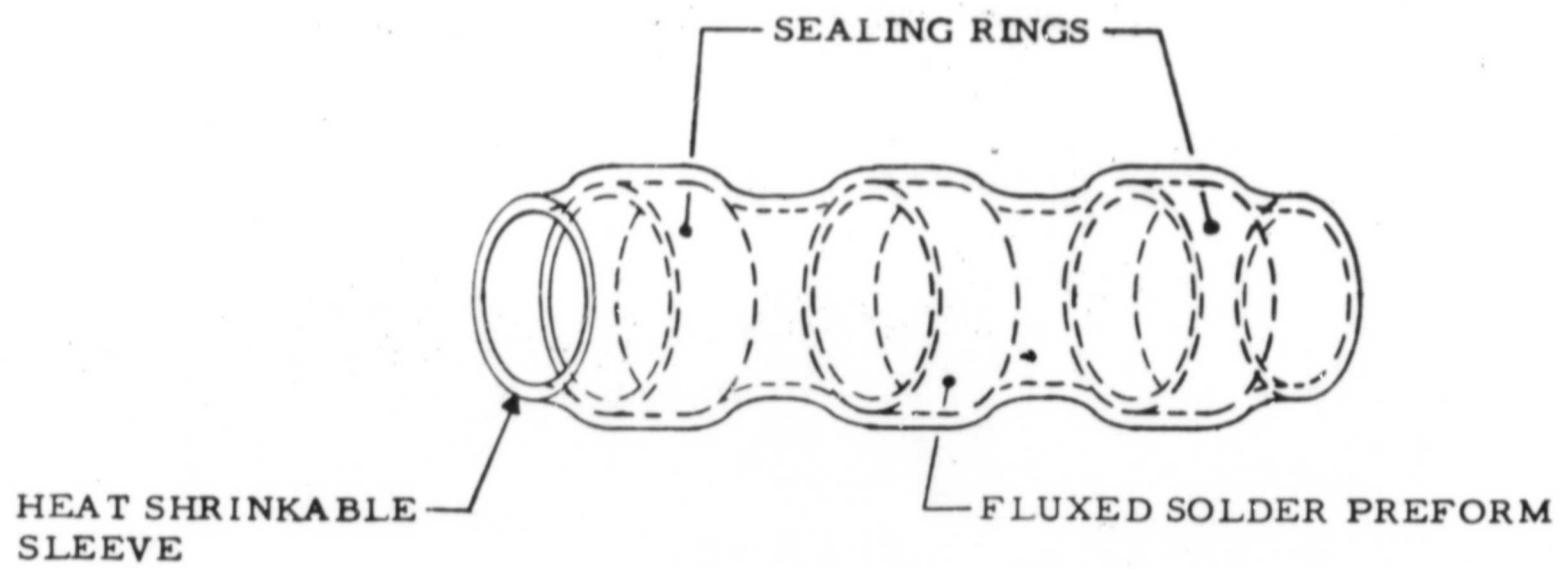


FIGURE 9-16 TYPICAL SOLDER SLEEVE

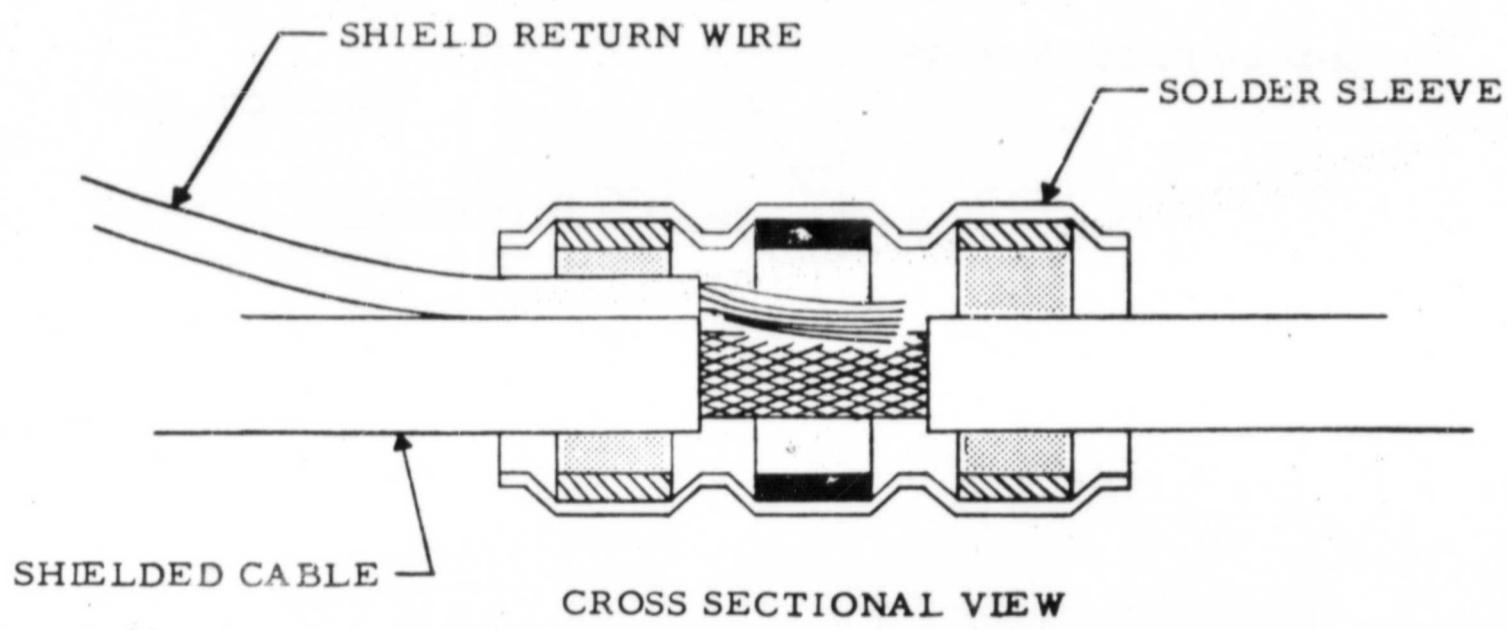
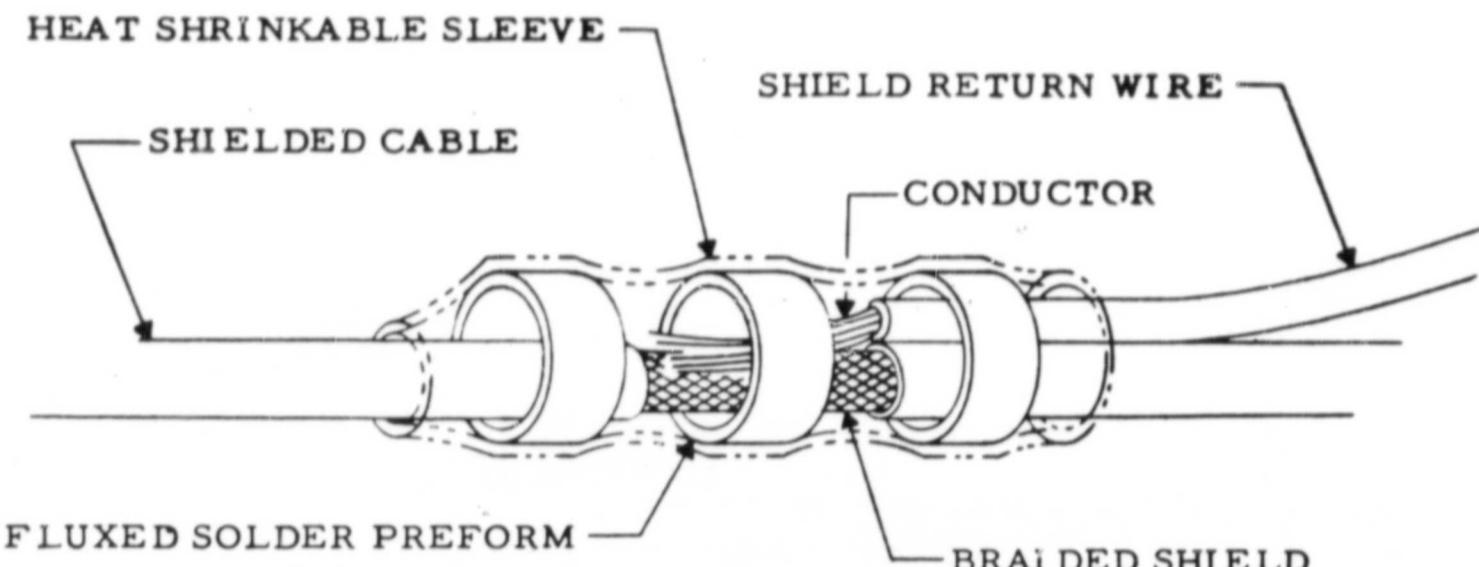
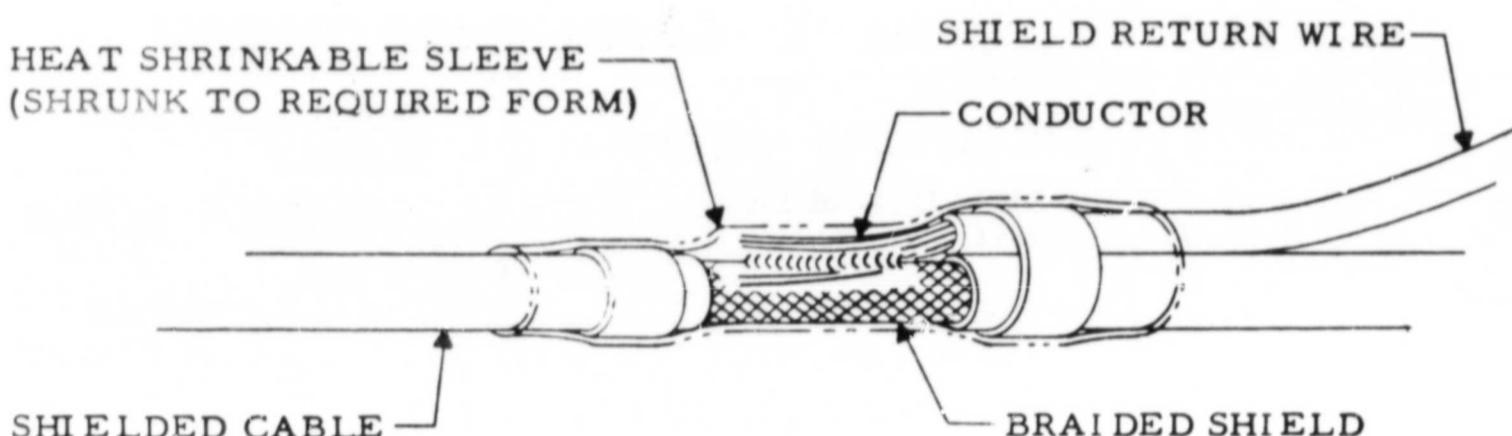


FIGURE 9-17 ASSEMBLY OF SOLDER SLEEVE



ASSEMBLY JUST PRIOR TO SOLDER FLOW



SOLDER HAS FLOWED

CONDUCTOR OF THE SHIELD RETURN WIRE AND THE BRAIDED SHIELD COMPLETELY COVERED BY SOLDER FLOW, AND PROPER FILLET BETWEEN CONDUCTOR AND BRAIDED SHIELD.

FIGURE 9-18 APPLICATION OF SOLDER SLEEVES

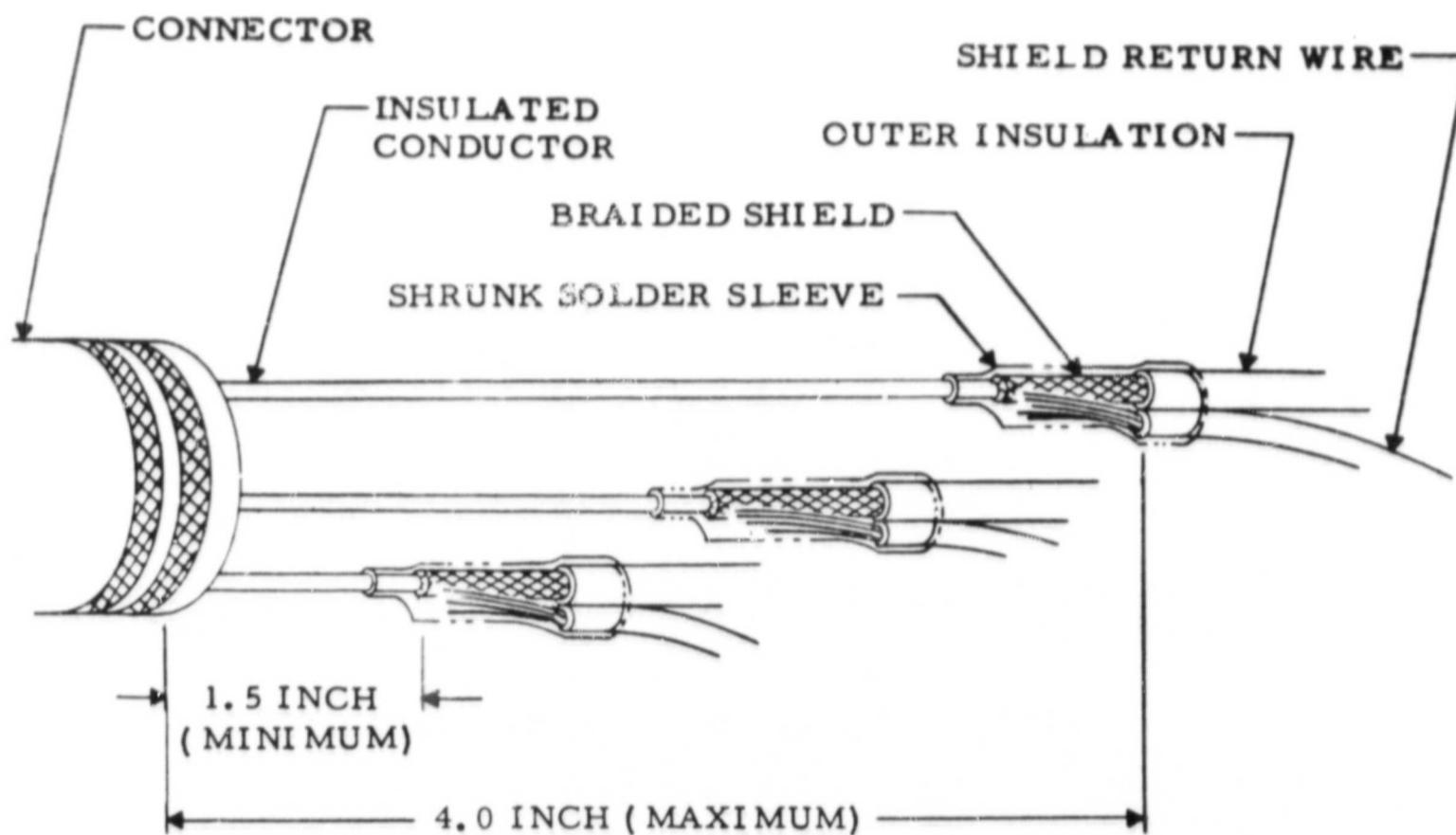


FIGURE 9-19 SOLDER SLEEVE, NOMINAL SHIELD COVERAGE

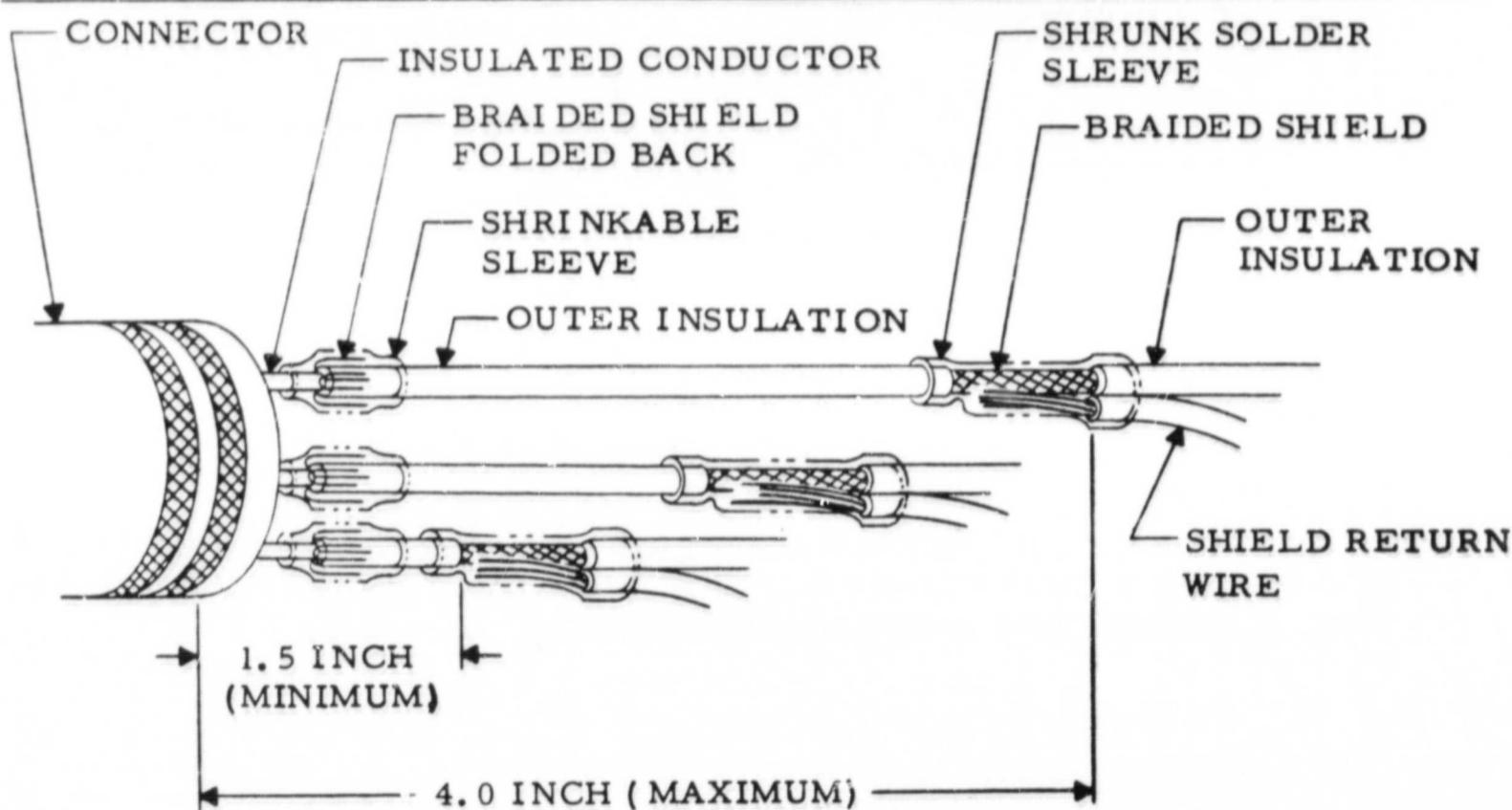
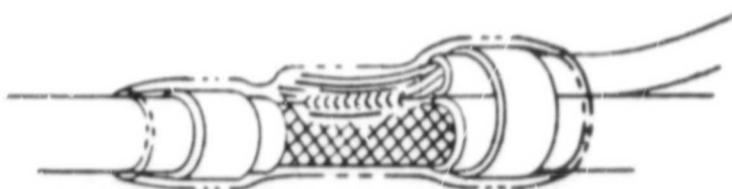


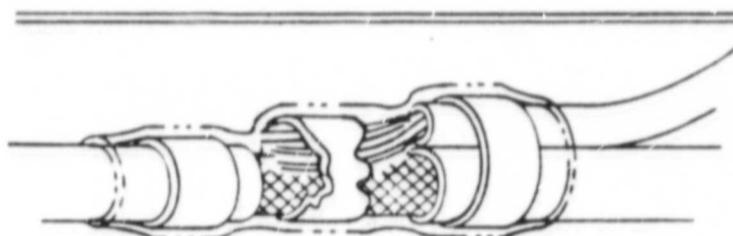
FIGURE 9-20 SOLDER SLEEVE, MAXIMUM SHIELD COVERAGE



**PROPERLY HEATED**

THE SOLDER HAS LOST ITS ORIGINAL RING SHAPE. THE WIDTH OF THE SOLDER CAN NO LONGER BE MEASURED. A GOOD FILLET OF SOLDER EXISTS BETWEEN THE SHIELD RETURN WIRE AND BRAIDED SHIELD.

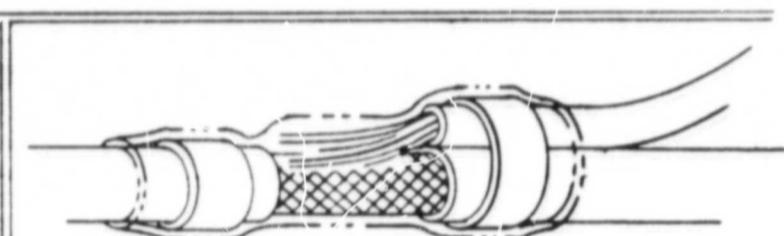
**ACCEPTABLE**



**UNDERHEATED**

THE SOLDER HAS COLLAPSED AND STARTED TO MELT. HOWEVER, THE WIDTH AND SHAPE OF THE SOLDER BAND ARE STILL VERY WELL DEFINED.

**UNACCEPTABLE**



**OVERHEATED**

THE EXCESS HEAT HAS CAUSED THE SOLDER TO WICK OR FLOW ALONG THE BRAIDED SHIELD. THIS HAS LEFT INSUFFICIENT SOLDER AT THE JOINT, AS INDICATED BY THE LACK OF A FILLET ALONG THE SHIELD RETURN WIRE AND BRAIDED SHIELD.

**UNACCEPTABLE**

**FIGURE 9-21 SOLDER SLEEVE ACCEPTANCE CRITERIA**

SECTION 10  
WIRE AND CABLE TERMINATION

10.1 GENERAL

This section establishes the requirements for crimping and soldering of electrical terminations.

10.2 PROCESS CONTROL REQUIREMENTS

The methods for preparing and assembling the parts to be joined by crimping or soldering, and the selection, calibration, use, and verification of the tools shall conform to the following paragraphs. Regardless of the process used (crimping or soldering), records shall be kept to provide identification between the finished product, the operator, and the tools or equipment utilized.

10.2.1 CLEANLINESS REQUIREMENTS

Work areas shall be maintained in a neat orderly fashion, with no loose material (trash, dust, oils, etc.) that can cause contamination of the crimped or soldered connection. Working surfaces shall be covered with an easily cleaned hard top, or shall have a disposable, non-corrosive covering. Smoking, eating, and drinking at the work stations shall not be permitted.

10.2.2 OPERATOR QUALIFICATIONS

Personnel involved in wire termination processes shall be trained and certified in the use of tools and equipment as described in MSC/MSFC JD-001, "Requirements for Crimping of Electrical Connectors", or NHB 5300.4 (3A), "Requirements for Soldered Electrical Connection", as applicable.

10.2.3 PROCESS VERIFICATION

Prior to performing wire/cable termination operations, verify that preceding operations such as wire/cable layout, cable shield terminations (where applicable), and stripping, have been performed and verified in accordance with applicable drawings and specifications. Make sure that wires/cables have not been damaged and wire/cable has been cut and stripped at the correct location for termination. In addition to the preceding process control requirements,

#### 10.2.3 PROCESS VERIFICATION (Continued)

the controls and procedures described in the following paragraphs shall be applied, as applicable to the termination method.

### 10.3 CRIMP CONTACT TERMINATIONS

Crimping operations for connector contacts (pins and sockets), shall be performed and controlled as described in the following paragraphs. Prior to performing crimping operations, the operator shall review all applicable materials, tools, and techniques which are planned for the work, to insure compatibility with the manufacturer's instructions and/or operator's planning procedures. The review shall cover each separate manufacturing step, and shall consider the type of wire (number of strands), plating metal, type and thickness of insulation, the type of contact (size, shape, and material), and the tools (type and calibration) which are needed to perform the operation. The criteria contained in this document, along with the requirements established in MSC/MSFC JD-001, shall be used as a guideline for assurance of proper and reliable crimp terminations.

#### 10.3.1 CRIMP TOOLING

The crimp method for making electrical connections consists of compressing the crimp barrel of the connector contact onto the wire or cable very tightly so intimate metal-to-metal contact is achieved. Therefore, it is essential that only factory set, non-adjustable crimping tools of the manual or power driven type are used, so the process can be controlled and the crimp can be easily and correctly made and reliably reproduced. Whenever practical, tools that provide four indents, as illustrated in Figure 1, shall be utilized for crimping connector contacts. In general, crimping tools should be selected that contain the following features:

- a. Provision for holding the contact in place while the wire or cable is inserted and the crimp started.
- b. A full cycle control so that the tool will not open and the contact cannot be removed until the crimp is completed.
- c. A bottoming feature which assures that the crimp is compressed to a specified dimension before the full cycle control allows the tool to open.
- d. Proper size, weight, and shape for easy and efficient operation.

#### 10.3.1 CRIMP TOOLING (Continued)

- e. Strong construction and dependable action to assure consistent crimp indentation.

#### 10.3.2 CALIBRATION AND CONTROL OF CRIMPING TOOLS

Crimping tools, both manual and power driven, shall be calibrated when initially set up, for each specific wire size, contact size, and type material. The crimping tool shall be calibrated and controlled in accordance with specification MSC/MSFC JD-001, "Requirements for crimping of Electrical Connections", and the criteria contained in this document. To establish proper in-process control, the following tests shall be performed upon sample crimped terminations in production:

- a. Tensile Strength - Tensile strength tests are performed to measure the force required to fracture the crimp joint between wire/cable and terminal. The tensile test is conducted by gripping the contact in one jaw and the wire/cable in the other jaw of a dependable tensile testing machine and pulling at a prescribed rate until fracture occurs. The recommended tensile tester used to perform the pull tests shall have an accuracy of  $\pm$  1/2 pound per 50 pounds. The movable jaw shall be adjustable to 1 inch per minute and shall be capable of maintaining this speed at  $\pm$  0.25 inch per minute. The terminal and wire/cable must be gripped in the jaws so the crimped area is not bent or otherwise affected. Sometimes it may be necessary to provide special holding fixtures so fracture does not occur at the jaws. It is advisable to provide 6 inches of wire/cable between the jaws of the testing machine so all of the wire/cable strands absorb the applied load. The connection shall show no damage when subjected to a minimum load of 75 percent of the wire/cable tensile strength. After determining that the joint possesses minimum strength, the load shall be increased to failure. The value of failure shall be recorded, together with whether the failure was pull out, break in crimp, or break in wire.
- b. Resistance Tests - The electrical resistance of a crimp termination is measured to determine its conductivity. The measured value of the crimp termination is compared to that of an equal length and size of wire/cable used in the crimp operation and expressed as the relative resistance for that particular wire/cable size. The relative resistance of crimp to the wire/cable is determined by passing a specified current

#### 10.3.2 CALIBRATION AND CONTROL OF CRIMPING TOOLS (Continued)

through the crimp termination and measuring the voltage drop. Properly designed and assembled crimp terminations will have resistance values lower than the wire/cable itself.

- c. GO-NOGO Gaging - From the tensile and resistance test results, a crimp depth setting within the allowable tolerances can be established by using the "GO" - "NOGO" gage specified for the contact size, and the wire/cable type and size. The gaging is performed by closing the crimp tool handles to the bottom of the stroke, so the crimp dies are butted and the tool ratchet is in the release position, and inserting the "GO" gage between the indenters from the protruding side of the positioner. The gage should pass through freely, thereby indicating that the indenters are not set too tight. This procedure is repeated with the "NOGO", but the gage shall not enter between the indenters. This proves that the indenters are not set too loose. Once the determination has been made that in the positive bottoming position the indenters are set correctly, then the ratchet release must be checked by inserting the "NOGO" gage between the indenters and gently closing the tool handles until the indenters touch the gage. When the handles are released the tool shall not bottom and shall not return to the fully open position.

CAUTION: Excessive hand pressure during tool closure will crimp the gage pin and cause possible damage to the indenter tips.

#### 10.3.3 CRIMPED CONTACT TERMINATION PREPARATION

Before attempting to produce crimped terminations, the operator should perform a review of the materials, tools, and techniques which are planned for the work to ensure compatibility with the applicable operations procedure. Upon completion of the procedure review, determine the wire/cable stripping length required for the particular crimp contact and remove the insulation using one of the processes defined in Section 8 of this document. For wire sizes AWG 30 through AWG 10, the maximum insulation gap shall be equal to the outside diameter of the wire being used. For larger wire sizes, the gap shall not exceed 1/4 inch. There shall be no minimum gap requirement, except that wire/cable insulation shall not be crimped in the contact barrel. Where the terminal or contact is supplied with insulation supports, the wire/cable insulation shall enter into the support sufficiently so that no bare wire is exposed.

#### 10.3.4 CRIMPING PROCEDURE

Termination of the wire/cable into the contact shall be performed as described in the following procedure:

- a. Place the contact in the positioner and observe if it is held in proper location. Usually the contact can be placed in the locator and the tool handles closed partially until the crimp dies just start to press on the contact, without compressing it. At this point the ratchet will lock the handles in position.
- b. Insert the stripped wire/cable in the crimp barrel until it bottoms, then push lightly to hold the wire/cable in the bottomed position. If the contact has an inspection hole, the stripped wires shall be visible in the hole. Do not push so hard that the wire/cable bends or the contact moves. Exercise care to assure that all conductor strands are inserted in the contact crimp barrel, and verify that insulation clearance meets the requirements established in paragraph 10.3.3.
- c. While holding the wire/cable in place, close the tool handles until the crimp dies bottom or butt together. The handles may now be released (they should open under their own spring pressure), and the crimped termination removed (reference Figure 2).

#### 10.3.5 CRIMP TERMINATION PROCESS VERIFICATION

After crimping, verify and record identification of the crimping tool and operator. Contacts shall be inspected to verify that the wire conductors are visible through the inspection hole (when applicable) and insulation does not extend into the crimped portion of the contact barrel. Assure that the maximum insulation gap does not exceed the outside diameter of the wire. The crimping indentations shall be in the proper portion of the barrel and there shall be no cracks, splits, or flaked plating on the crimped contacts. Also, the contacts shall not be bent.

#### 10.4 SOLDER CONTACT TERMINATIONS

Wires and cables to be terminated in solder type connectors shall be prepared and soldered in accordance with the procedures, requirements, and controls established in NHB 5300.4 (3A), "Requirements for Soldered Electrical Connections", and the following paragraphs.

#### 10.4.1 SOLDERING EQUIPMENT AND MATERIALS

The solder method for making strong electrical connections requires heating the solder joint to a temperature of 500° - 550° F. for 1 to 2 seconds and applying rosin cored solder to complete the solder connection. Therefore, it is essential that the size, wattage, and shape of the soldering iron be carefully selected to approach these conditions as closely as possible. When the tip is applied to the connection joint, it should rapidly heat the joint to soldering temperature. The solder used for completing the joint should contain a core of rosin flux to aid solder flow.

#### 10.4.2 WIRE PREPARATION

Prior to soldering wires or cables to connector contacts, the wires/cables shall be pre-tinned to assure solderability. Tinning of the wire/cable should extend only far enough to take full advantage of the connector solder cup and should be accomplished as described in the following procedure:

- a. Determine the wire stripping length required for the particular solder termination and remove the insulation as defined in Section 8 of this document.
- b. Add a small amount of solder to the tip of the iron, and then place the wire on top of the solder and allow to heat.
- c. When the wire has reached the temperature of the iron, solder will flow into the strands. At this time, a small amount of solder is applied to the wire. Solder is then allowed to flow until the wire has absorbed enough to tin every strand.

NOTE: Tinning may be accomplished by dipping the wire into a solder pot.

#### 10.4.3 CONNECTOR PREPARATION

Prior to soldering wires/cables to connector contacts, the connector shall be disassembled (i.e., backshell, ferrule, and grommet), when applicable. Preparation of the connector shall include cleaning of both sides of the connector to assure that the surfaces are free of oil, dirt, grease, and any foreign materials. If present, these substances shall be removed by wiping with a clean lint-free cloth dampened with a suitable cleaning solvent, followed by wiping with a clean dry cloth. Also, a clean soft brush may be used to remove loose contaminates.

#### 10.4.3 CONNECTOR PREPARATION (Continued)

NOTE: When tightening or loosening threaded parts or connectors, support all plug assemblies by mating with the proper receptacle, or by holding them with an approved plug wrench.

After the wires/cables have been prepared and are ready to be soldered to the connector contacts, slide the connector, wire guide grommet, backshell, and wire sealing grommet (when required), onto the wires/cables a sufficient distance so as not to interfere with the soldering operation.

NOTE: If difficulty is encountered in passing wires through the sealing grommet, the wire may be cut on an angle of 45 degrees. In this case, stripping and tinning of the wire is performed after passing the wire through the grommets.

#### 10.4.4 JOINING WIRE/CABLE TO CONNECTOR

The connection should be firmly mounted with the open end of the cups facing the operator. The wires should be soldered in rows, progressing from bottom to the top. To properly solder the wire or cable to a connector, the following procedure is recommended:

- a. Insert a small piece of solder in the cup and heat by holding the flat side of the soldering iron against the lower side of the cup, until the solder is completely melted. Keep the heat on the terminal until all trapped flux comes to the surface.
- b. Insert the tinned wire into the molten solder until the wire bottoms in the cup. The conductor should be in contact with the back wall of the cup, and the end of the insulation should be far enough from the soldered joint that the insulation cannot be embedded in the solder, yet not so far as to permit a short circuit between two adjacent wires. In general, the length of the gap should be a distance equal to approximately the wire diameter.
- c. Remove the iron and hold the conductor steady until the solder cools and hardens. A smooth fillet should be formed between the conductor and the inner wall of the cup, as illustrated in Figure 3. All outside strands should be clearly discernible adjacent to the insulation.
- d. After the solder has solidified, clean the joint using a bristle brush dipped in isoprophyle alcohol or other approved solvent to remove flux residues.

#### 10.4.4 JOINING WIRE/CABLE TO CONNECTOR (Continued)

- e. After the solder connection has been verified, slide a piece of insulation tubing over the soldered connection. When the connector is to be potted, a protective sleeve over the wire and contact shall not be installed.
- f. Assemble the connector as described in Section 11 of this document.

#### 10.4.5 SOLDERED CONTACT PROCESS VERIFICATION

After soldering, record identification of the operator. Soldered contacts shall be inspected to verify that the solder joint meets the requirements of NHB 5300.4 (3A). The quality of the soldered connection can be determined by visual inspection. Wires should not be pulled or bent, nor force exerted on the connection to test the mechanical soundness of the connection. Since the wire should not be bent or forced, it is necessary to inspect in steps when later assembly will make the solder joint impossible to inspect.

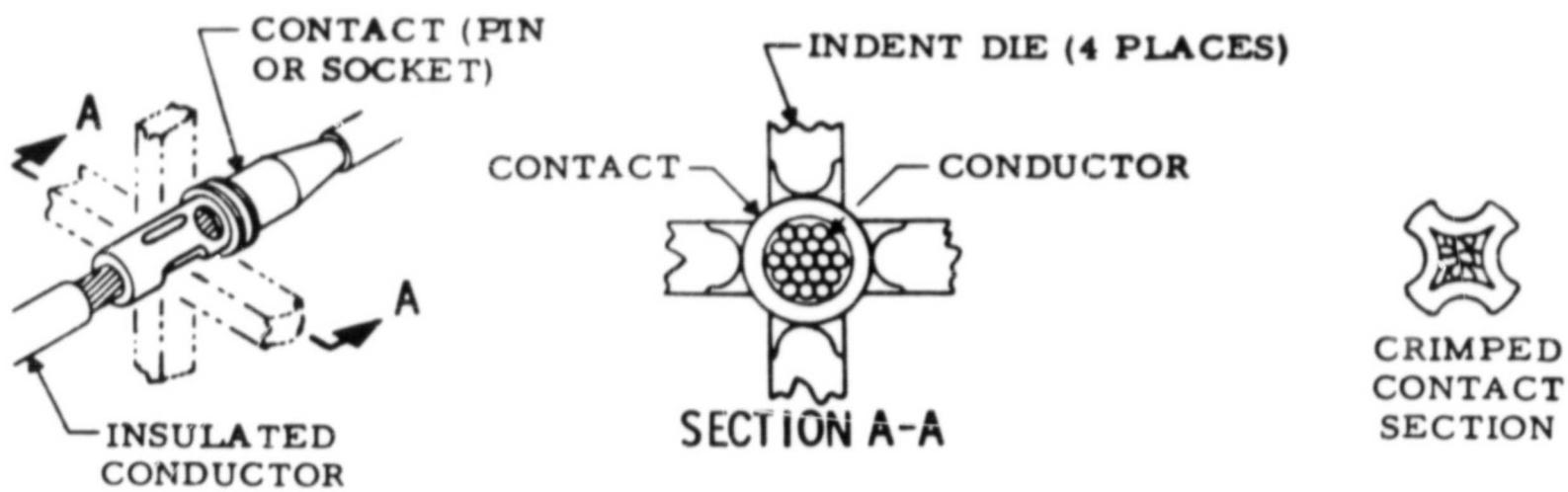


FIGURE 10-1 FOUR INDENT CRIMP

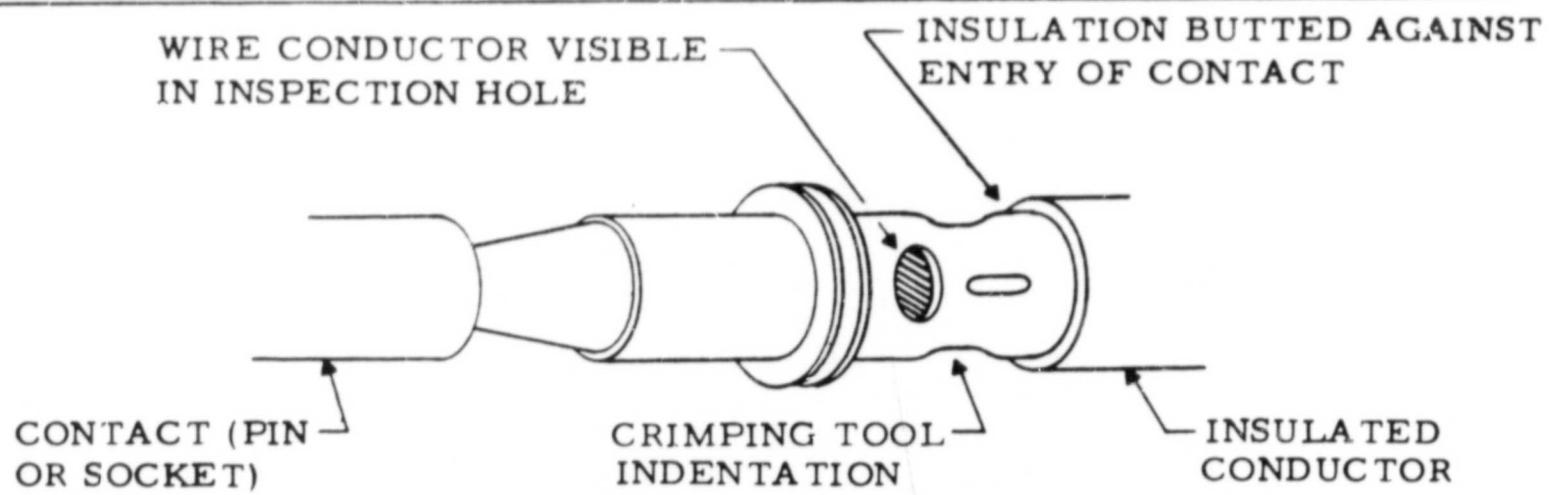


FIGURE 10-2 TYPICAL CRIMPED CONTACT

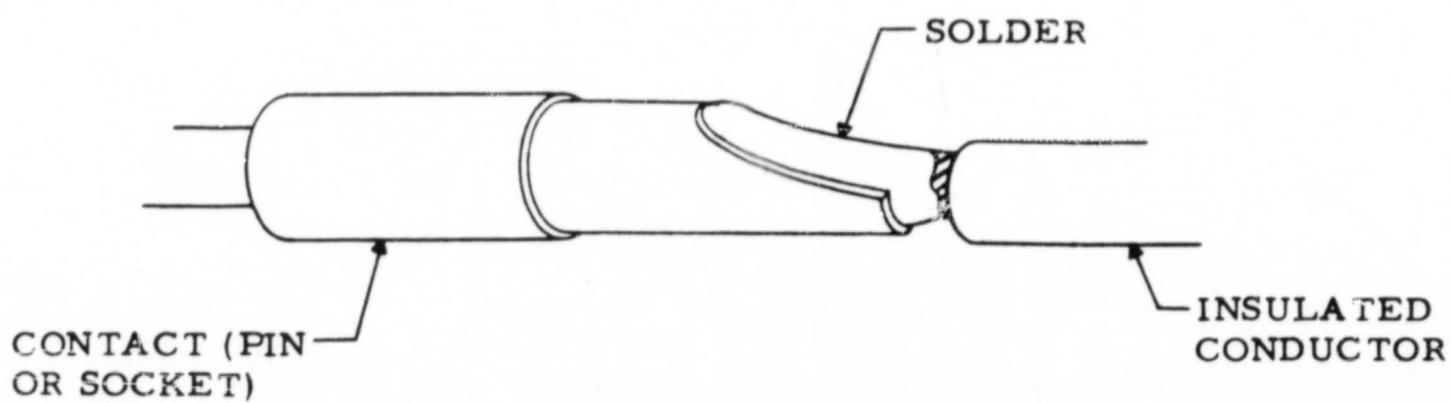


FIGURE 10-3 PROPER SOLDER CUP TERMINATION

## SECTION 11

### CONNECTOR ASSEMBLY

#### 11.1 GENERAL

This section describes the procedures and process controls relative to installation of crimped contacts into connectors, and assembly of both crimp and solder type connectors. Elements relative to termination of wires/cables by crimping or soldering are contained in Section 10 of this document and should be referred to, prior to connector assembly operations.

#### 11.2 PROCESS CONTROL REQUIREMENTS

Prior to performing the wiring or assembly of any connector, verify that all wire and cable has been cut, stripped, and terminated (when applicable) in accordance with the previous process requirements. Visually examine each connector and associated hardware to assure that the contacts are not bent or recessed, the finish is not damaged, and the interface grommet, wire termination and rear insert are free from foreign material, grease, dirt, etc. Check grommet area for imperfections such as mold flash, cuts, gouges, or obvious damage to the sealing area of the connector. Verify that connector coupling devices are free of burred or scored coupling nut threads or damaged clocking key(s).

##### 11.2.1 CONNECTOR PROTECTION

All connectors shall have caps or other protective devices installed throughout all stages of fabrication and testing, except when connected with mating connectors, or during individual connector testing. When caps are removed for pin insertion, testing, cleaning, etc., the caps shall be replaced promptly after the operation is completed.

##### 11.2.2 CONNECTOR CLEANING

Prior to assembly or after disassembly of a connector, the contacts and inside surface of the connector shall be kept free of all oil, dirt, grease, and any other foreign material. If present, these substances shall

### 11.2.2 CONNECTOR CLEANING (Continued)

be removed by wiping with a clean lint free cloth dampened with a suitable cleaning fluid, followed by wiping with a clean dry cloth. Also, a clean soft brush may be used to remove loose contaminates on interfacial seals.

## 11.3 ASSEMBLY OF CRIMP TYPE CONNECTORS

Preparatory to inserting contacts into crimp type connectors, the operator shall assure that the contact insertion and removal tools are of the correct type, and are in acceptable working condition. Damaged tooling shall not be used. Insertion and removal tools shall be inspected prior to, and after completion of work on each connector. In addition, tooling fixtures shall be provided to support the wires/cables and connector while installing the crimped contacts. After applicable tools have been obtained and verified, the wires/cables shall be inserted in the connectors, and connectors assembled, as described in the following paragraphs.

### 11.3.1 CONTACT INSERTION (REAR ENTRY TYPE)

After the contacts have been crimped (Reference Section 10) to the wires/cables and are ready to be installed in the connector, slide the connector, wire guide grommet, and the back shell assembly onto the wires.

NOTE: The backshell assembly supplied with the connector shall be installed unless otherwise specified on the applicable engineering drawing.

To install the contacts in the connector, the insertion/extraction tool is snapped around the wire insulation with the tip of the tool butting against the rear shoulder of the contact. The contact, axially aligned with the cavity, is then inserted into the proper cavity in the rear of the connector and pushed forward until it bottoms in the insert. When inserted, the tangs on the retaining clip will snap into position behind the contact shoulder. A slight "click" should be heard at this point. The tool is then removed leaving the contact held securely in the insert. Continue in a like manner to install the remainder of the contacts. Spare contacts shall be installed in unused insert cavities. It is recommended that the center contacts be inserted first then continue working outward. When completed, a visual inspection shall be made at the mating end of the connector to be sure all contacts are properly inserted and secured to an equal distance.

CAUTION: Do not use insertion tools that have damaged insertion tips.

Visually inspect the tool to insure that tool tips are not

### 11.3.1 CONTACT INSERTION (REAR ENTRY TYPE) (Continued)

bent or otherwise deformed and are free of burrs, nicks, or sharp edges.

### 11.3.2 CONTACT INSERTION (FRONT ENTRY TYPE)

The following paragraphs outline the procedure for installation of contacts in connectors designed for contact insertion from the front of connector inserts.

**CAUTION:** Care must be taken when inserting wires through connector inserts. DO NOT strip wires prior to insertion through inserts.

- a. Slide the connector, wire guide grommet, and back shell assembly onto the wires.
- b. After inserting the wire through the predetermined hole in the connector insert, strip the wire insulation in accordance with Section 8, and crimp on the contact in accordance with Section 10.
- c. Draw the terminated wire or cable back through the front of the connector insert until the contact is halfway into the contact cavity.
- d. Select the proper size insertion tool and carefully push the contact into place. Apply evenly the force required to seat the contact into the proper retained position.
- e. Remove the insertion tool by pulling the tool straight back out of the connector.

**NOTE:** Installation of the contacts in rectangular connectors can be simplified if installation is started on one side of the connector and progressed directly across. Random insertion of contacts should be avoided.

**CAUTION:** When inserting contacts through a connector grommet, exercise care to avoid an abrupt insertion or removal which does not allow sufficient time for the grommet material to flow or stretch around the contact and insertion tool.

- f. Visually inspect the mating end (front) of the connector to be sure all contacts are properly inserted and secured to an equal depth, and are aligned correctly in respect to other contacts. Spare contacts shall be installed in unused insert cavities.

#### 11.3.3 SEALING OF UNUSED CONNECTOR GROMMET HOLES

Every unused grommet hole shall be filled with a sealing plug. The sealing plug shall be inserted by hand. (Reference Figure 1.)

#### 11.3.4 BACKSHELL INSTALLATION

Slide the backshell forward and hand tighten to connector shell, making sure that the wire sealing grommet does not become distorted during the tightening process (Reference Figure 2). For clocking of angle connector backshells, a maximum deviation of  $\pm 15^\circ$  (degrees) from the specified clocked position shall be allowed (Reference Figure 3).

#### 11.3.5 STRAIN RELIEF OR CABLE GUIDE TYPES

All connectors that have strain relief or cable guide clamps shall have a grommet or other approved protective material installed between the wire bundle and the wire guide or strain relief clamp. This is to prevent chafing and to maintain the relative position of the wiring at the cable exit. Cushioning shall be applied on straight cable runs as well as on cable runs that exit at an angle from wire guides or strain relief clamps. Allow sufficient slack within the backshell cable guide clamp so that tightening the cable clamps will not place a strain on the terminations or cause a visible opening between the wire and the grommet sealing webs. (Reference Figure 4.)

#### 11.3.6 TIGHTENING CONNECTORS

Connectors with threaded couplings shall be tightened, as far as travel permits, by hand to permit proper alignment and prevent damage to the threads. Support the connector with a mating connector or connector body, except base type, as illustrated in Figure 5. Specified torquing shall then be accomplished.

#### 11.3.7 CRIMP TYPE CONNECTOR PROCESS VERIFICATION

Examine the completed connector to assure that all applicable provisions of this document and applicable engineering documents are complied with. Particular care shall be exercised to assure that the assembled connector is free of such defects as:

### 11.3.7 CRIMP TYPE CONNECTOR PROCESS VERIFICATION (Continued)

- a. Imperfections in the grommets extending into the chamfer (wire sealing) area.
- b. Obvious splits, cuts or gouges of the grommet.
- c. Missing or improper "o" ring.
- d. Connector contacts with cracked or flaked plating, tarnished or corroded surfaces.
- e. Recessed or protruding contacts, or missing contacts.
- f. Bent or mis-aligned pins.
- g. Visible dirt, grease, or other foreign materials.
- h. Connector coupling devices that are loose, binding, or have burred or scored coupling threads.
- i. Damaged clocking key(s).
- j. Strain relief clamps with burrs or sharp edges, excessive thread protrusion, or backshell over/under torqued.
- k. Protective finishes that are scratched, dented, or damaged so that the base metal is exposed.
- l. Missing or wrong size protective dust caps.
- m. Missing sealing plug in grommet.

### 11.4 ENVIRONMENTALLY SEALED SOLDER TYPE CONNECTORS

Preparatory to the wiring of the connector, disassemble the connector by removing the grommet compressing sleeve retaining screws, grommet compressing sleeve or braid retaining adapter, sealing grommet and clamping nut; remove the items in the aforementioned order. On potted type connectors, remove the potting end bell. Mate the connector with a dummy or actual mating part during the disassembly process.

#### 11.4.1 WIRE/CABLE INSTALLATION

Prior to soldering the wires in the connector, the connector shall be appropriately fixtured so that during and after the soldering process, the wires are axially aligned with the connector contacts. Feed the wires through the compressing sleeve or connector adapter and then through the sealing grommet and clamping nut. Wires must pass through the grommet hole which corresponds to the location of the contact to which the wires will be soldered. Match the letters on the grommet with the letters on the insert so that the grommet and wires are properly aligned. On potted type connectors, feed the wires thru the end bell.

#### 11.4.2 SOLDERING OF WIRES/CABLES

After the connector has been disassembled, located in an applicable fixture, and wires/cables passed through the grommet, the wires/cables shall be soldered to the connector contacts in accordance with the requirements of paragraph 10.4 of this document. All unused sealing grommet holes shall be filled with the sealing plugs furnished with each connector. The plugs shall be installed as shown in Figure 1, at the time of connector assembly.

#### 11.4.3 CONNECTOR ASSEMBLY

Carefully examine the rear of the connector insert for foreign particles and wire strands, and to make sure that each bared conductor is not kinked or bent. Assemble the connector as described in paragraphs 11.3.4, through 11.3.6.

#### 11.4.4 SOLDER TYPE CONNECTOR PROCESS VERIFICATION

Examine the completed connector to assure that all provisions of this document and applicable engineering documents are complied with. Particular care shall be exercised to assure that the assembled connector is free of such defects as:

- a. Imperfections in the interfacial grommet extending into the chamfer (wire sealing) area.
- b. Obvious splits, cuts, or gouges of the grommet.
- c. Missing or improper "o" ring
- d. Connector contacts with cracked or flaked plating, tarnished or corroded surfaces.
- e. Bent or mis-aligned pins.
- f. Visible dirt, grease, solder flux, or other foreign materials.
- g. Connector coupling devices that are loose, binding, or have burred or scored coupling threads
- h. Damaged clocking key(s).
- i. Strain relief clamps with burrs or sharp edges, excessive thread protrusion, or backshell over/under torqued.
- j. Protective finishes that are scratched, dented, or damaged, so that the base metal is exposed.
- k. Missing or wrong size protective dust caps.

## 11.5 ASSEMBLY OF COAXIAL CONNECTORS

The assembly of coaxial contacts and connectors shall be accomplished as defined in the applicable manufacturer's instructions; however, the manufacturer's instructions must not be relied on for final instruction. Detail instructions must be derived through process engineering, for the materials specifically involved. Process engineering shall result in a coaxial connector/cable assembly of the highest reliability. Disassembly of samples shall assure that the torquing requirements are sufficient, the stripping and trimming dimensions are optimum, and that all applicable materials are appropriately placed. Both soldered and crimp type contact terminations are acceptable. Cables shall be stripped, prior to termination, as described in Section 8 of this document. The cable termination operation (crimp or solder) shall be performed and controlled by the requirements established in Section 10 of this document, as applicable. Regardless of the type of coaxial connector used, or the method of termination (crimp or solder), the process verification standards established in the following paragraph shall apply.

### 11.5.1 COAXIAL TYPE CONNECTOR PROCESS VERIFICATION

Examine the completed connector to assure that all applicable provisions of this document and applicable engineering documents are complied with. Particular care shall be exercised to assure that the assembled connector is free of such defects as:

- a. Tarnished or corroded contacts.
- b. Bent or misaligned pins.
- c. Visible dirt, grease, solder flux, or other foreign material.
- d. Coupling device that is loose, binding, or damaged.
- e. Protective finishes that are scratched, dented, or damaged so that the base metal is exposed.

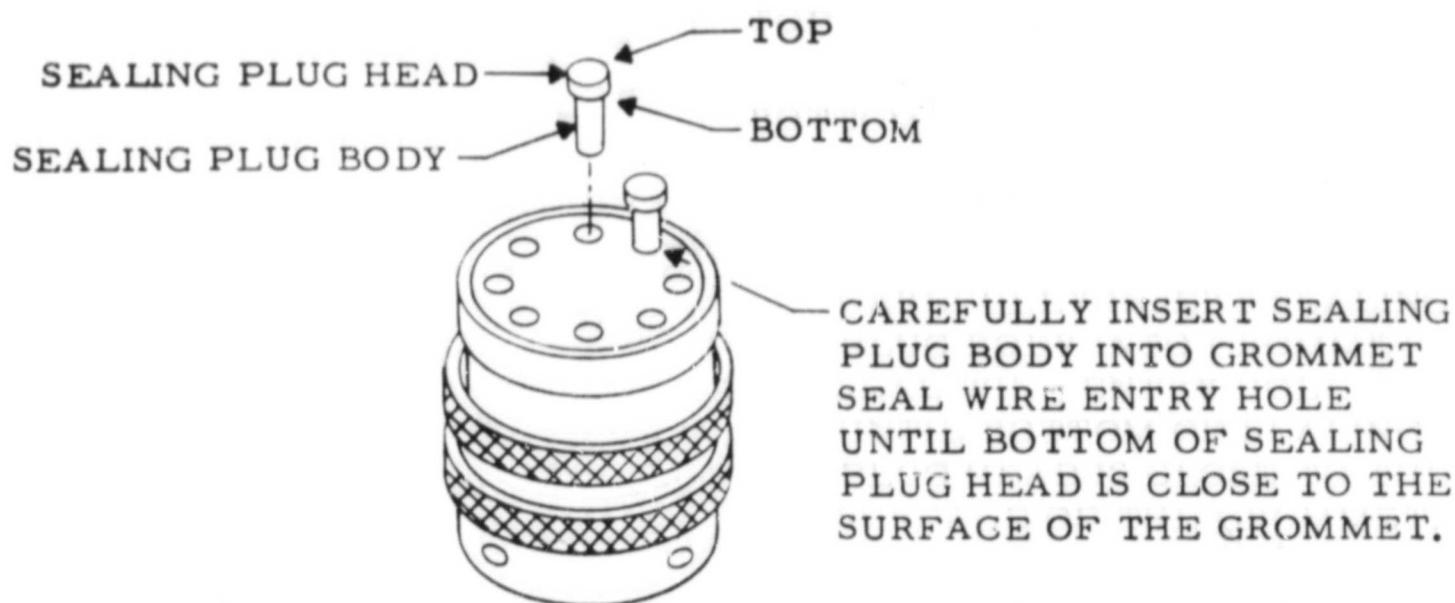


FIGURE 11-1 SEALING PLUG INSTALLATION



FIGURE 11-2 STRAIN RELIEF CLAMP

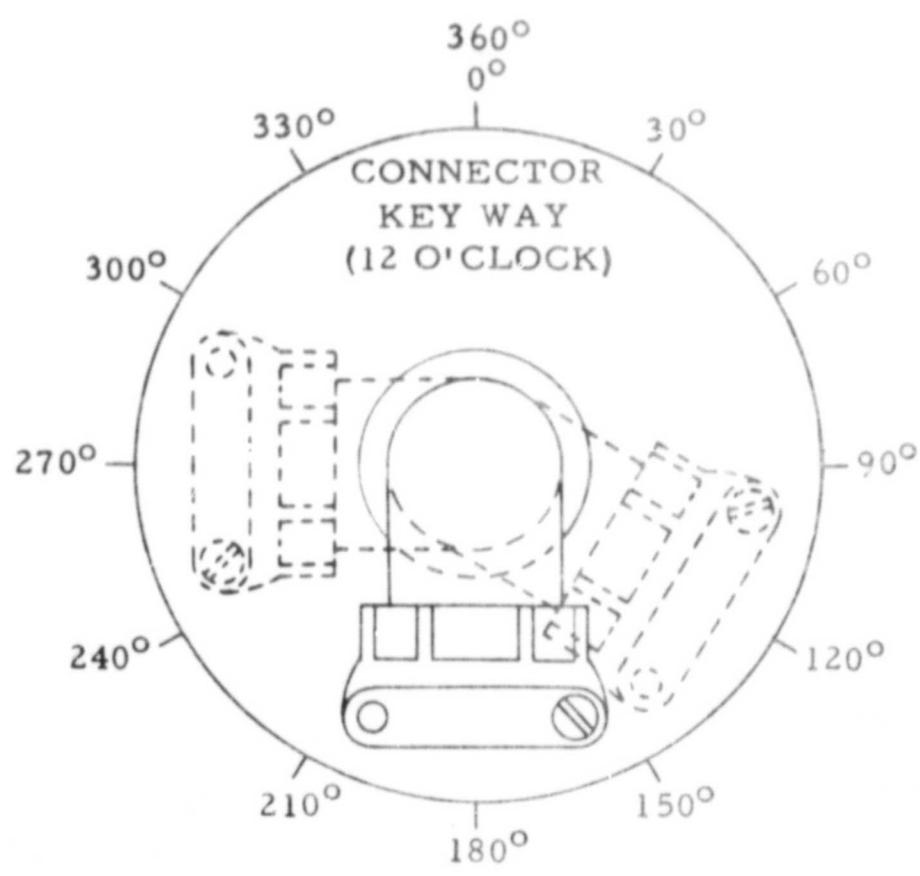


FIGURE 11-3 ALIGNMENT OF 90° CONNECTORS

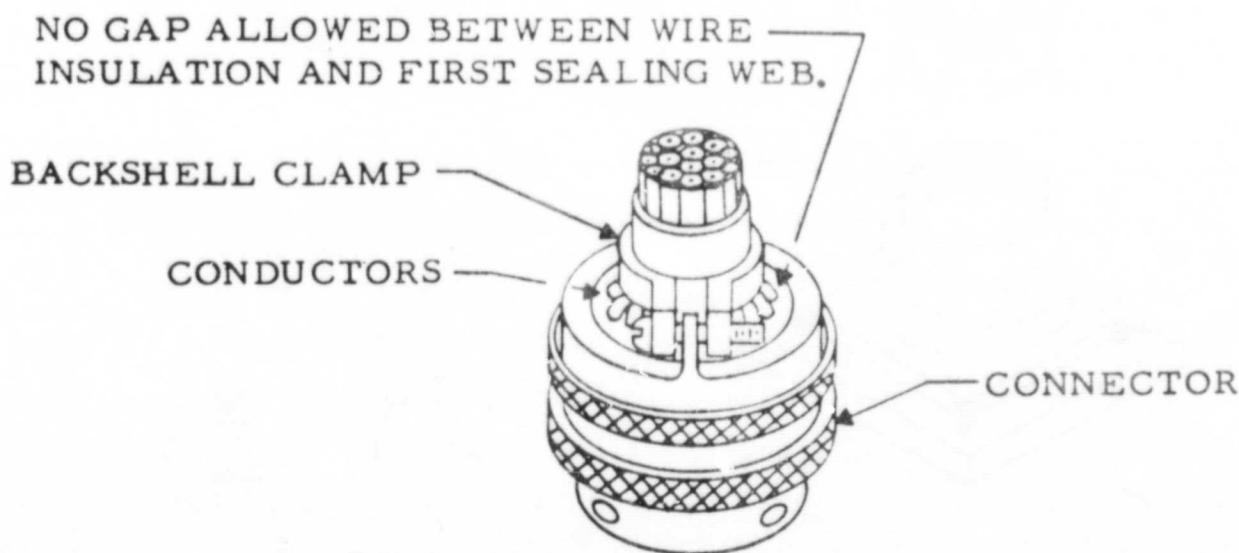
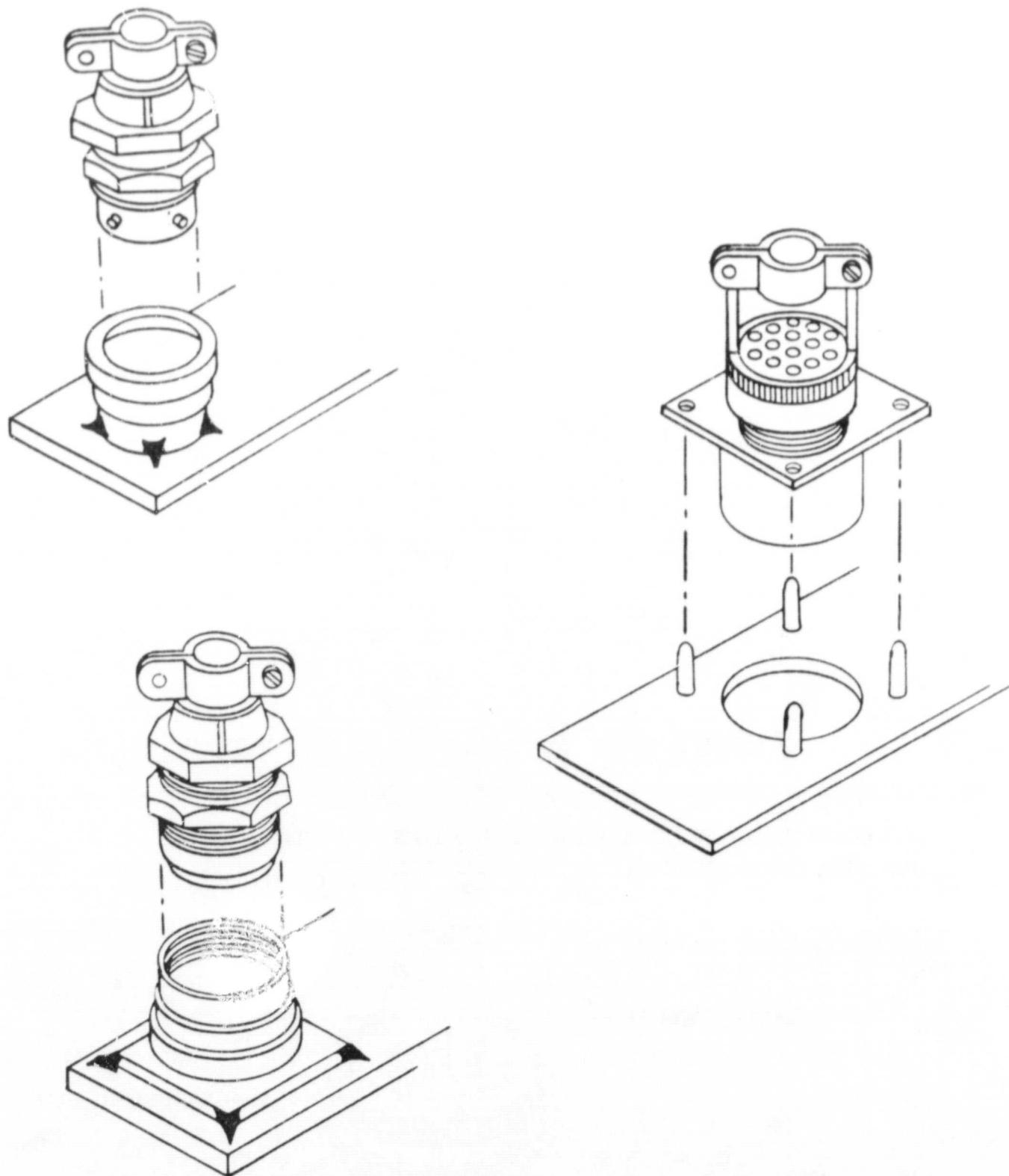


FIGURE 11-4 ALLOWABLE CONDUCTOR DEFLECTION



**FIGURE 11-5 BASIC TYPES OF CONNECTOR HOLDING DEVICES**

## SECTION 12

### POTTING ENCAPSULATION

#### 12.1 GENERAL

This section establishes the standard process for potting electrical connectors used in the fabrication of harness assemblies, by using epoxy resin potting compositions. The criteria contained in this section conforms to, and shall be used in conjunction with all requirements of MSFC-PROC-196, "Potting Cable Assemblies Using Epoxy Resin Compounds".

#### 12.2 PROCESS CONTROL REQUIREMENTS

Prior to the potting operation, verify that the harness assembly bears evidence of inspection acceptance for compliance to design requirements, workmanship, and electrical testing. Care shall be taken to assure that all loose wire strands, solder particles, and other foreign material, such as oil, dirt, or grease, has been removed from the connector and cable harness areas to be potted. If contaminants are present, they shall be removed by wiping with a clean lint-free cloth, dampened with a suitable cleaning solvent, followed by wiping with a clean dry cloth. When necessary, a clean soft bristle brush may be used to remove loose contamination on interfacial connector seals. Verify that connector coupling rings (when applicable) rotate freely, and all connector contacts are properly aligned and not recessed or protruding.

##### 12.2.1 CONTROL AND CLEANLINESS OF POTTING FACILITY

The potting facility shall be isolated from such contaminants as dust, metallic particles, water, oil, and grease. Bench tops shall be protected from spillage by disposable paper coverings, and floors shall be cleaned frequently with an acceptable cleanser. The temperature of the potting facility shall be maintained at  $24 \pm 2$  degrees Celsius; and the relative humidity shall not exceed 55 percent. Adequate ventilation shall be provided to accommodate the volume of compounds, solvents, and primers being used. Forced-draft ventilation, where toxic fumes are generated, is necessary and fumes shall be drawn away from the operator and vented to the outside.

#### 12.2.2 EQUIPMENT

The potting area should be equipped with air pressurization equipment capable of delivering moisture-free air (maximum 90 psig), and a vacuum system capable of producing a differential pressure for removing trapped air from the potting compound. Accurate weighing equipment shall be provided for measuring the epoxy constituents. The injection gun shall be either a manual or air-operated calking gun equipped with a disposable plunger, liner, and nozzle. In addition, holding racks should be available to hold the harness components rigid and in proper alignment.

#### 12.2.3 HANDLING PRECAUTIONS

All personnel that are engaged in potting encapsulation shall demonstrate proficiency in producing high quality end items, and be trained in proper handling procedures. In general, the chemicals involved are safe when properly handled by trained and qualified personnel, but when carelessly handled, the materials utilized for potting may cause severe physiological reactions. The following criteria shall be implemented, in conjunction with manufacturer's instructions, to insure safe handling procedures:

- a. Avoid contact with solvents, primers, and compounds with the skin. Protective clothing shall be changed when soiled by potting materials. Special care shall be taken to prevent contact with open breaks on the skin.
- b. Avoid ingestion and inhalation of vapors.
- c. If the eyes are accidentally contaminated, flush with water and obtain medical attention immediately.
- d. Areas of the skin exposed to solvents, primers, and compounds shall be cleaned with an approved cleaner and then with a nonabrasive soap and clean water. Personnel shall not smoke or eat until after thorough cleansing of exposed skin areas.
- e. No smoking or open flames shall be allowed within 25 feet of an operation where compounds, primers, and solvents are being used. "NO SMOKING" signs shall be displayed in conspicuous places.

#### 12.3 HARNESS PREPARATION

To insure proper adhesion of the potting compound to all components of the

### 12.3 HARNESS PREPARATION (Continued)

connector, the inner body of the connector, wires/cables, boot, and all other materials that will contact the compound must be clean and free from any trace of contaminants. Caution must be exercised during cleaning to insure that wire/cable insulation and connector inserts are not exposed to cleaning solvent to the extent that swelling or other indications of damage occur. Upon completion of cleaning, primer shall be applied to the wire/cable insulation above the area to be covered with the potting compound and to all surfaces of the connector coming into contact with the potting compound. The primer shall be cured in accordance with manufacturer's instructions.

### 12.4 POTTING COMPOUND PREPARATION

Prior to preparing the potting compound, verify that the resin and activator have been successfully acceptance tested and that the shelf life has not expired. The following procedures should be followed in preparing the compound for application:

- a. Place the resin and activator (in the proper proportional ratios) in a clean, dry, nonporous container having at least four times the capacity as the volume of the combined parts. Blend the resin and activator thoroughly by mechanical agitation or by stirring with a clean spatula. Avoid fast stirring that may entrap excessive air.
- b. Place the container in a vacuum chamber and apply a vacuum. Maintain the vacuum until foaming subsides, but not more than 10 minutes.

### 12.5 POTTING REQUIREMENTS

The potting process shall conform to all requirements of MSFC-PROC-196; facilities, equipment, safety precautions, personnel proficiency, and process controls shall be fully complied with. Upon verification of the preceding requirements the potting process shall be performed as described in the following procedure:

- a. Transfer the mixed compound from the mixing container to the injection gun cartridge by carefully and slowly pouring the compound down the side of the cartridge, using care not to entrap air, until the desired level in the cartridge is reached. Put the plastic plunger in place and insert the cartridge into the gun. Attach the correct

## 12.5 POTTING REQUIREMENTS (Continued)

size nozzle for the applicable potting job and adjust the air pressure supply to approximately 15 psig.

- b. Test the injection gun for free and even flow of compound from the nozzle.
- c. Prepare a hardness test sample from each mixed batch by using a small container to make a "button" of the compound (approximately 1 inch in diameter by 0.750 inch thick). Cure according to the same schedule assigned to the job it is taken from. The button shall accompany the cable throughout the remainder of the cure cycle.
- d. Immediately prior to potting, check the connector coupling ring to assure that it rotates freely.
- e. Carefully separate the conductors in the connector, taking special care not to damage any conductors or contacts.
- f. Position the nozzle in the center of the contacts near the connector insert.
- g. The potting shall extend upon the cable sheath a minimum of 0.250 inch or if open wire, it shall extend upon the conductor insulation a minimum of 0.250 inch.
- h. When conductors are shielded, the shield terminations shall be embedded in the connector potting.
- i. Start the flow of the compound, assuring an even flow around the pins.
- j. Keep the nozzle tip at the swell level and continue the injection until the required level is attained. Let the compound settle a minimum of 5 minutes and replenish to the required level.
- k. Cure the potting compound as recommended by the manufacturer.
- l. Check the connector coupling ring to assure it rotates freely after potting.

## 12.6 EXAMINATION OF POTTING

The potted harness assembly shall be examined for general appearance and quality of workmanship. The surfaces of the potted area shall be free from voids, blisters, tackiness, soft spots, cracks, discoloration, lumps, non-adherence, or any defect indicative of low quality resin or poor workmanship. The hardness of the resin shall be determined by three readings, using the D scale of a Shore Durometer, or equivalent. The readings shall be made on a

12.6 EXAMINATION OF POTTING (Continued)

flat surfaced sample "coupon" prepared and processed per MSFC-PROC-196.

CAUTION: Care shall be used in handling and examination of assemblies potted with epoxy resins. The rigid, sharp edges of the cured resins in contact with the cable sheath may cut, mar, or mutilate the sheath material, if the harness is forcefully handled.

## SECTION 13

### HARNESS IDENTIFICATION

#### 13.1 GENERAL

This section defines the requirements for both temporary and permanent identification of harness assemblies and connectors, including the criteria for temporary markings that are necessary to facilitate harness installation.

#### 13.2 TEMPORARY HARNESS IDENTIFICATION

Temporary identification for scheduling and process control which is not required for the finished assembly is permissible. Such identification markers shall not adversely affect the assembly, and shall not appear on the completed harness.

##### 13.2.1 TEMPORARY IDENTIFICATION METHODS

Tagging may be used to temporarily identify harnesses, although identification-marking-by-packaging shall be used in preference to tagging for harnesses which can be placed in a package conveniently. When used, tags shall be of cloth or pressed fiber, and shall be legibly marked by impression stamping or other permanent method using characters at least 3/32 inch high. Tags shall be securely attached to the harness with cord, or by wrap around in a manner that will not damage the assembly in processing, shipment, or storage. Application of adhesive tags is not recommended due to the possibility of harness contamination.

#### 13.3 PERMANENT IDENTIFICATION REQUIREMENTS

The type of permanent harness and connector identification markers used on open bundle harnesses may differ because of the applications. Specific criteria relative to application of marking methods and type of markers which may be used are described in applicable paragraphs of this section. Regardless of marker type, the requirements established in paragraphs 13.3.1 through 13.3.6 shall apply.

### 13.3.1 PROCESS CONTROL

Before application of the permanent harness and connector identification markings, verify that the harness assembly has completed the applicable sections of this document, and design engineering requirements. Verify that the harness configuration and temporary harness identification agree with the design engineering drawings, and connector "P" and "J" numbers are correct. After removal of the temporary identification markers, verify that harness surface is not contaminated or damaged such as cuts, nicks, or abraded areas.

### 13.3.2 IDENTIFICATION

The combination of letters and numbers which constitute the identification code shall be in accordance with applicable drawings, specifications, and standards. Unless otherwise specified on the applicable drawings, identification shall be applied directly to a piece of insulated sleeving or a band marker, as applicable. Application of identification shall not cause damage to the sleeve or marker, and the identification shall be applied so that it cannot be readily rubbed off. Identification markers shall withstand the same temperatures and other environmental conditions to which the harnesses are subjected.

### 13.3.3 HARNESS ASSEMBLY IDENTIFICATION

The harness reference designation and part number shall be stamped on a band marker or insulated sleeve as described in the applicable procedures and as illustrated in Figure 1. The marker or sleeve shall be placed as close as possible to the connector strain relief clamp of the lowest alpha numbered connector (P1 or J1) on the wire harness, but not more than 12 inches from the connector.

### 13.3.4 CONNECTOR IDENTIFICATION

A band marker or insulated sleeve marked with the applicable connector reference designation and mating part reference designation, shall be located adjacent to each connector as illustrated in Figure 2.

### 13.3.5 ACCESSIBILITY

The identification shall be installed so that it is readable from the normal point of observation. Specifically, if there is a choice of installing

### 13.3.5 ACCESSIBILITY (Continued)

the identification "upside down" or "right side up" from the normal point of observation, the identification should be installed "right side up". The numbers may read either toward or away from the terminated end of the harness. An objective shall be to position all identification markers on the harnesses so as to provide maximum visibility after installation. Every effort shall be made to locate identification so that clamps and support devices do not have to be removed, or the harness twisted, in order to read the identification.

### 13.3. LEGIBILITY

All identification characters shall be legible, permanent, and colored (where applicable) to contrast with the surface on which the identification is placed. The characters shall be of sufficient size and color to provide ease of identification through fabrication, checkout, and mission duration.

## 13.4 IDENTIFICATION OF HARNESSES

All open bundle harness assembly identification criteria shall be marked by direct application on band markers or by means of a stamped piece of sleeving. Regardless of the method selected, an attempt shall be made to use the same method for all identification purposes so that uniformity can be maintained. All identification markers shall be firmly secured to the harness so as to prevent loss of markers from shock and vibration.

### 13.4.1 MARKING EQUIPMENT

Band marker and sleeve identification marking shall be accomplished with calibrated marking machines as specified in the applicable process specification or manufacturer's instructions for detailed calibration and operation of the machine. Marking shall be performed utilizing a marking machine with automatic foil and work feeds (optional), adjustable temperature and thermostatically controlled marking head, with adjustable pressure and dwell time. Marking materials (such as foils and inked ribbons) shall be selected to correspond with the base material being identified.

### 13.4.2 MARKING PROCESS CONTROL

Prior to hot impression marking of the identification bands and sleeves,

#### 13.4.2 MARKING PROCESS CONTROL (Continued)

assure that:

- a. Band marker or sleeving is free of dust, grease, or other foreign matter.
- b. The correct size and curvature of type is selected per the manufacturer's instructions. Curved faced marking type shall be used for marking sleeving, which is supported by a mandrel. Flat faced type shall be used for marking identification plates, bands and sleeving not supported by a mandrel.
- c. Marking machine has received periodic inspection and maintenance at intervals that will assure that the machine and accessories are in good operating condition. Marking foil is the correct type required for the type sleeving or band material to be marked.

#### 13.4.3 APPLICATION

Identification shall be imprinted on band markers or sleeves using an approved method which will not impair the quality of the marker or sleeve. When the direct stamping process is used for band markers or sleeve identification, the following procedure shall be used:

- a. Regulate the pressure, indicate type temperature and dwell time for each material to provide maximum transfer of pigment from foil to the material being imprinted, and for best legibility. Use the lowest pressure and shortest dwell time that will produce a legible and permanent imprint, to prevent penetration of the type through the material.
- b. Use characters of sufficient size and machine adjustments necessary to provide markings for best legibility.
- c. To prevent uneven depth marking, make sure that type faces are clean and that all characters are set in the same plane. Plated and unplated type may be of different depths and should not be used together.

#### 13.4.4 STAMPED INSULATION SLEEVE IDENTIFICATION METHOD

Harness identification criteria may be applied by affixing marked, non-metallic sleeves imprinted with the applicable identification data. Sleeving material shall withstand the same temperatures and other environmental conditions to which the wire harness is subjected. When the harness identifica-

13.4.4 STAMPED INSULATION SLEEVE IDENTIFICATION METHOD (Continued)  
tion criteria is applied utilizing sleeves, the following procedure shall  
be used:

- a. Select the correct size sleeve to fit over the harness. Where possible, the sleeve should be snug enough so that subsequent string ties are unnecessary. Where it is impractical to use whole sleeves, heat shrinkable or otherwise, the sleeve may be split and tied at each end, but select a sleeve diameter to provide an overlap a distance of 1/4 the diameter.
- b. Apply the identification markings to the sleeve using the direct stamping application procedure described in paragraph 13.4.3.
- c. Cut the sleeving so that each length includes a complete identification. The sleeve shall be no longer than necessary to include all identification information plus a margin for clarity.
- d. Locate the identification sleeves on the wire harness as described for the applicable identification requirement.

#### 13.4.5 BAND MARKER IDENTIFICATION METHOD

Identification of wire harnesses may be accomplished by affixing marked, non-metallic band markers or identification plates imprinted with the applicable identification data. All band markers, identification plates, and adjustable cable straps used for identification purposes shall be per design standard 40M39582. When harness identification criteria is applied utilizing band markers, the following procedure shall be used:

- a. Select the desired size identification plate and strap (if required) to fit over the harness.
- b. Apply the identification markings to the plate using the direct stamping application procedure described in paragraph 13.4.3. Flat-face type and foil must be used. More than one number, or row of numbers may be stamped on a single band marker.
- c. Place the plate and strap(s) around the wire bundle and run strap tip through the hub. The ribs must be placed against the wire bundle. Pull the strap(s) tightly around the wire bundle by hand.
- d. Tighten strap(s) using manufacturer's recommended tool and procedure, taking care not to damage the wire harness, and cut excessive strap length.

### 13.5 LOCATION MARKER IDENTIFICATION

Non-metallic identification markers may be installed on the harness assemblies to reference and identify specific locations during harness installation. Band markers or insulated sleeves shall be stamped with applicable stringer, station, frame, azimuth, grid, or plane location markings, and located on the harness to aid in installation and configuration control.

### 13.6 IDENTIFICATION PROCESS VERIFICATION

Visually examine the final harness and connector identification markings to assure that:

- a. The identification marker material is of the correct type and style.
- b. The identification marking agrees with applicable engineering drawing.
- c. Lettering or numbering is legible.
- d. Identification markers are located properly.

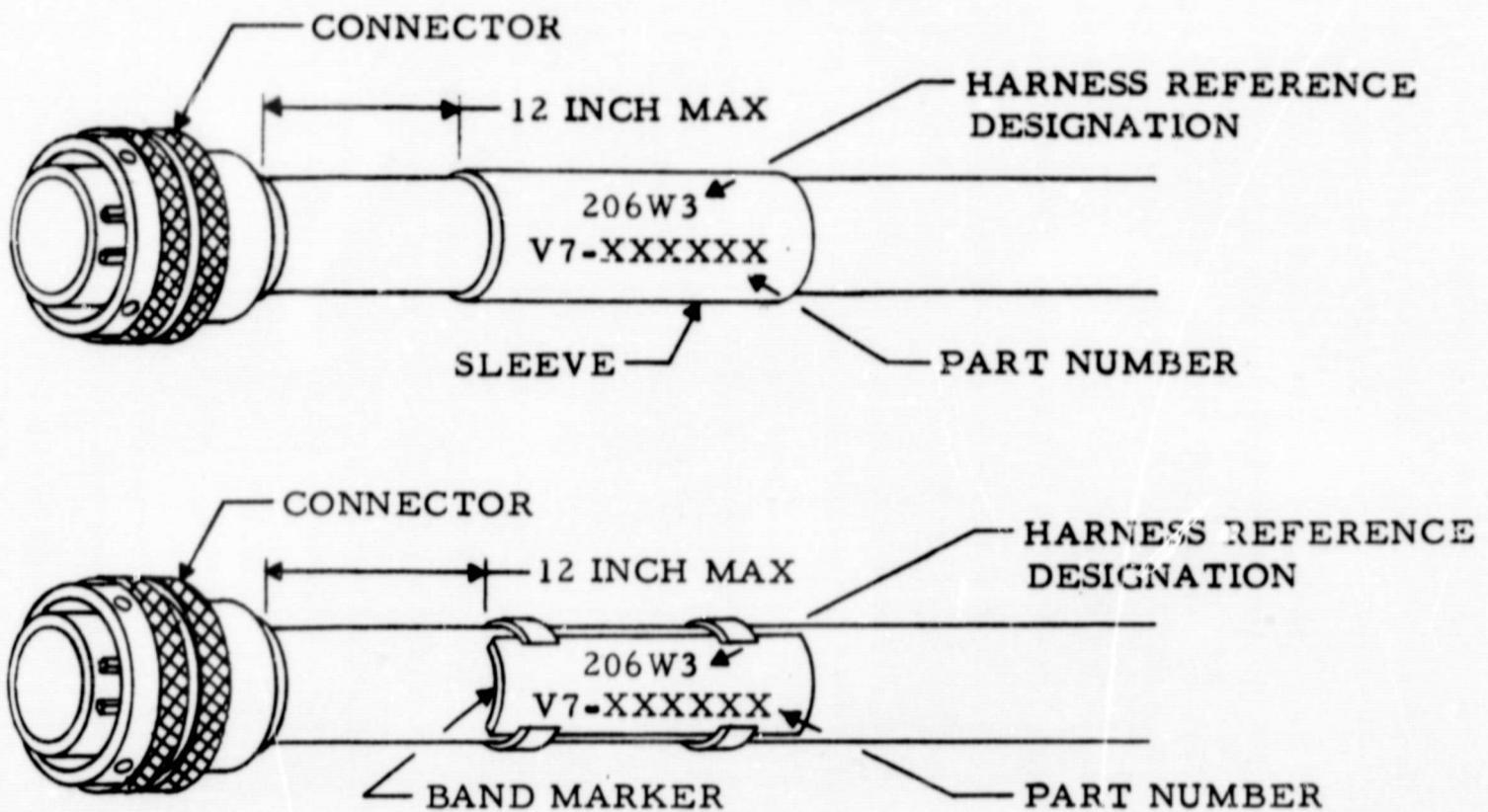


FIGURE 13-1 IDENTIFICATION OF HARNESS ASSEMBLY

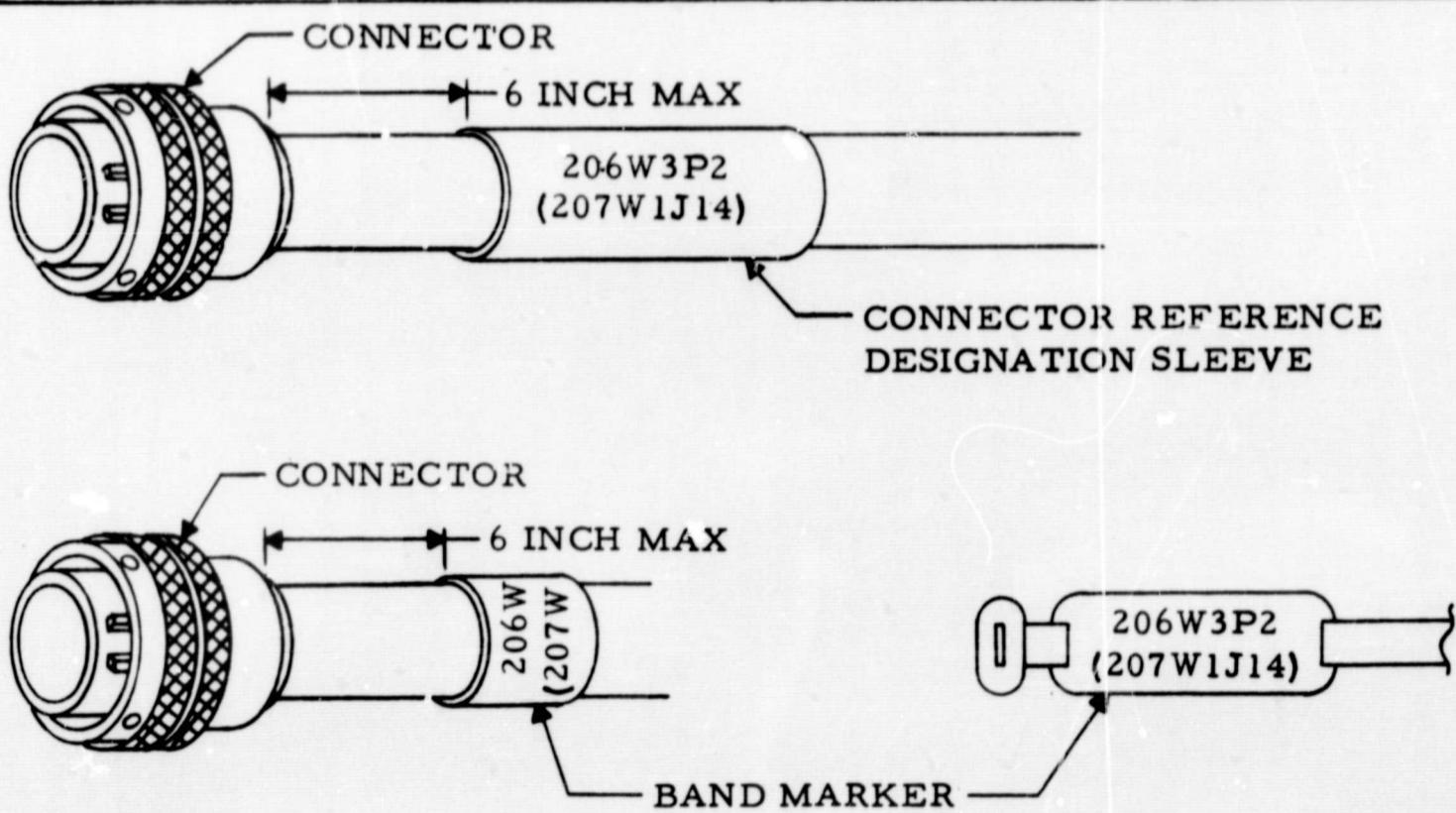


FIGURE 13-2 IDENTIFICATION OF CONNECTOR PLUGS

SECTION 14  
HARNESS CLEANING

14.1 GENERAL

This section establishes the procedure for cleaning harness assemblies after completion of final fabrication and test.

14.2 PROCESS CONTROL REQUIREMENTS

Prior to cleaning, assure that the harness assembly has successfully met all previous quality and design requirements. The handling of the harness during cleaning operations described in the following paragraphs shall be performed with clean, lint-free gloves. In addition, verify that the facilities environmental controls are within requirements stated in the following paragraphs, prior to start of cleaning.

14.2.1 FACILITY REQUIREMENTS

Final harness cleaning and sealing shall be accomplished in a class 100,000 level clean room that complies with the intent of MSFC-STD-246A. The temperature shall be +68°F to +78°F, and relative humidity shall be 60%, or less, if necessary to preclude condensate forming. The garment requirements shall be coveralls, caps, and shoe covers. Records shall be maintained of the facilities environmental levels, with daily checks of temperature and humidity, and a minimum of three times a week for airborne particulate. Daily checks shall be accomplished to assure positive pressure differential and air flow of at least 40 FPM.

14.3 CLEANING OF HARNESS ASSEMBLIES

Completed harness assemblies shall be cleaned with either isopropyl alcohol (FED-SPEC-TT-I-735, Grade A) or ethyl alcohol (FED-SPEC-O-EO-760) to remove all contamination and foreign matter. The cleaned harness shall be examined under white light and black (ultra-violet) light for compliance to the following. Visual examination shall be limited to those surfaces which are accessible.

**CAUTION:** Use of other than the above cleaning agents may result in degradation to the connector materials and possible damage to

14.3 CLEANING OF HARNESS ASSEMBLIES (Continued)

the wire insulation.

14.3.1 VISIBLY CLEAN (WHITE LIGHT)

Visibly clean shall be construed to mean the freedom of surface contamination such as scale, dust, dirt, corrosion, and other foreign particulate matter, including grease, oil, or other forms of volatile contamination. Scale-free discoloration and specific surface treatments shall not be considered visual contamination.

14.3.2 BLACK LIGHT (ULTRAVIOLET)

When viewing harnesses under black light, any evidence of foreign fluorescent matter on the harness or connector surfaces shall be cause for recleaning.

14.3.3 CLEANING OF CONNECTORS

Prior to the final installation of the protective connector covers, the interior and exterior of each connector shall be examined under both white and black light to verify freedom from grease, finger prints, or oily substances. Particles of dust or dirt, which are observed, shall be removed by use of a vacuum.

SECTION 15  
HARNESS HANDLING, PACKAGING AND SEALING

15.1 GENERAL

This section establishes and defines the methods and requirements for handling, protection, and sealing of harness assemblies.

15.2 PROTECTION LEVEL CRITERIA

Electrical harness assemblies require varying degrees of protection at all times. The performance and/or reliability of a harness assembly can be directly affected by the lack of adequate packaging or protection during in-process handling, storage, and shipment. Harness assembly protection shall be considered as the application of protective measures to prevent damage from physical and climatic environments during intra/inter facility handling, in-process, transportation, and storage operations.

15.3 APPLICATION

The appropriate level of harness protection shall be implemented by the manufacturing planning documents, and shall provide the necessary information required to assure adequate protection from the initial processing of the wire and cable, through shipment of the finished harness assembly.

15.4 IN-PROCESS HARNESS ASSEMBLY HANDLING PROTECTION

Harness handling shall be done carefully and held to a minimum to reduce the possibility of connector damage and work-hardening, or fatigue of the wiring. All connectors shall be protected with suitable snug-fitting plastic or metallic dust caps, except when it is necessary to work directly upon them, or when mated. Terminal junction devices and/or wire ends shall be protected singularly in a nylon bag and secured. Care is required in handling harness assemblies which have been cleaned and packaged to prevent damage or rupture of the outer wrap or packaging

#### 15.4.1 INTRA-INTER PLANT PROTECTION

Whenever harnesses are required to be transported to a service or repair area, they shall be packaged for shipment so that the harness does not become damaged. Connectors shall be individually wrapped with nylon bags and cushion material to prevent damage to themselves or other parts of the harness.

### 15.5 FINAL HARNESS ASSEMBLY SEALING AND PACKAGING

Prior to the sealing of the completed and cleaned harness assembly, assure that all design criteria and cleaning requirements have been performed and are acceptable. Verify that each connector is protected with a plastic or metallic cap and over-wrapped with a nylon bag. Terminal junction devices and/or wire ends shall be protected singularly in nylon bags and secured.

#### 15.5.1 HARNESS ASSEMBLY SEALING

Coil the harness assembly to form a minimum loop of at least twenty (20) times the diameter of the main harness trunk. Assure that connectors and/or terminal junction devices are adequately protected and cannot damage harness wire insulation or jacketing. Additional cushion material may be installed at this time. Place the harness into a clean nylon bag and purge with dry nitrogen (MIL-P-27401, Type 1), and immediately heat seal; then overbag with antistatic polyethylene film, 6 mils thick and heat seal. Identify the sealed harness per paragraph 15.5.4.

#### 15.5.2 HARNESS ASSEMBLY PACKAGING

Prior to packaging, assure that the sealed harness assembly wrapping is free of pin holes, tears, or cuts, loose or damaged closures, or broken cleanliness certification decals.

#### 15.5.3 PROTECTIVE CONTAINERS

The harness shall be placed into a suitably sized cushioned container. The container construction and material shall be of such integrity to provide positive protection from physical and climatic environments during storage and transportation. The container size shall be selected so that the harness generally fills the container, but does not interfere with closing of the

#### 15.5.3 PROTECTIVE CONTAINERS (Continued)

container. Additional cushion material may be added to firmly hold the harness and prevent excessive movement.

#### 15.5.4 IDENTIFICATION

Each cleaned and bagged harness assembly and container shall have an identification label or tag attached to the sealed harness (may be inserted between the nylon and polyethylene bag) and attached to the outside of the container, or inserted in the container, if the label or tag can be viewed from the outside. The tag or card shall carry the following information:

Drawing/Part Number \_\_\_\_\_

E.O. \_\_\_\_\_

Serial Number \_\_\_\_\_

Inspected by \_\_\_\_\_

Contract Number \_\_\_\_\_

"This harness assembly has been cleaned in accordance  
with Section 16, Harness Cleaning."

SECTION 16  
HARNESS INSTALLATION

16.1 GENERAL

This section establishes the installation criteria that pertains to Type IV (Open Bundle), interconnecting wire harnesses. The intended application of Type IV harnesses is for general use in areas outside the crew compartment.

16.2 PROCESS CONTROL REQUIREMENTS

Prior to installation of the completed harness assembly, verify that the harness has satisfactorily complied with all applicable processes, controls, and requirements of this document and applicable engineering design drawings. Assure that the harness has successfully passed functional testing and has been cleaned in accordance with Section 14 of this document. Special care shall be taken to assure that the harness packaging is free of physical or environmental damage, and identified in accordance with Section 15. Before routing the harness assembly, verify that the area is ready for the harness, and that all sharp edges, protrusions, or structural members are covered with protective material as specified in the following paragraphs.

16.2.1 SAFETY

The applicability of safety measures and the required scope of compliance shall be determined by the Safety Representative. Care shall be exercised during the performance of the installation requirements of this document. Good workmanship practices are essential to the safety of personnel installing the finished product, and to the equipment in which the wire harness may be an integral part.

16.2.2 FACILITIES

All wire harnesses shall be unpackaged and installed in a clean area. The general working area shall be maintained in a clean and orderly condition at all times. Only tools, fixtures, test equipment, etc., which are required to perform the task shall be allowed in the area.

### 16.3 HARNESS PROTECTION CRITERIA

A complete visual inspection shall be made of all surfaces coming into contact with wire harnesses to verify that no sharp or rough edges exist. Protective devices shall be installed to provide permanent harness protection from abrasion or other damage. Protection shall be installed where harnesses are routed across protruding or sharp edges of structures; through or across unprotected holes or cutouts; where wiring can contact protruding rivets or other fasteners; and at any location where the danger of chafing the harness exists. Particular attention shall be given to harness slack in this respect. The following paragraphs establish criteria for determining harness protection requirements. Techniques for eliminating potential damage conditions are described in paragraphs 16.4 through 16.4.3.

#### 16.3.1 CHAFING

Wire harnesses must be protected against damage that may result from rubbing against a surface or edge, or against any other object. Locations of possible abrasion damage (chafing) to the harnesses are as follows:

- a. Where a harness passes around a corner of a shelf, bracket, equipment, or structure.
- b. Where a harness passes through a hole, and a cushioned clamp or grommet alone is not adequate.
- c. Where a harness is exposed to excessive contact by personnel or equipment.
- d. Where harnesses pass near sharp edges of bolts, nuts, or rivets.

#### 16.3.2 HARNESSES ON OR NEAR MOVING PARTS

Harnesses that are attached to assemblies where relative movement occurs, or near rotating parts, shall be installed and protected in such a manner as to prevent damage caused by movement. This deterioration includes abrasion caused by one wire harness rubbing against another or by twisting and bending. Wire harnesses should be rerouted or protective devices shall be installed to provide permanent wire protection from abrasion and/or other damage. Harnesses shall be installed to twist instead of bend across hinges, although bending of harnesses at gimbal locations is acceptable.

## 16.4 PROTECTIVE DEVICES AND TECHNIQUES

Where wire harnesses pass near sharp or abrasive surfaces and may come in contact with such surfaces due to stresses during handling or flight, the harness shall be suitably protected to avoid any damage. As an objective, the minimum amount of protective material shall be used in order to save weight and aid maintenance. To accomplish this, routing of the harness shall avoid the necessity for protective materials to the greatest possible extent. The following paragraphs describe the devices and techniques for providing harness protection when required.

### 16.4.1 PROTECTIVE GROMMETS

Where harnesses are routed over, or may contact any protrusions or sharp edges, protection of the harnesses will be provided by covering the protrusion or sharp edge with Teflon cushion or equivalent material. Where harnesses are routed over or through structural members that have Teflon caterpillar-type grommets, rigid grommets, or any protrusions and sharp edges, the harness should be supported by clamping to prevent the possibility of chafing. Figures 1 and 2 illustrate typical installations where grommet protection would be applied. When necessary to trim grommets to obtain proper fit, the gap after installation shall not exceed 1/10 inch. The angle of the cut shall be 45 degrees to the axis of the wire harness.

### 16.4.2 PROTECTIVE CLAMPING

Approved clamps shall be used to maintain the separation between any surface and the wire harness assembly. Harnesses shall be prevented from moving inside the clamp by selecting the proper clamp size and installing it with adequate tightness (see Section 17, "Support and Clamping"). Clamps used to support and separate harnesses from adjacent surfaces shall be attached to structure for support whenever possible. If supporting structure is not available, the clamps may be attached to lines carrying inert fluids such as water, helium, or nitrogen. (For lines carrying flammable fluids, see paragraph 16.5.2.) If the clamps are attached to the lines carrying inert fluids, the clamps shall be located close to those clamps which support the line itself. Wires and cables shall not depend on insulating tubing to maintain a separation from any adjacent surface; except that insulating tubing shall enclose the wires and cables when they lie on the inner surface of metallic conduit.

#### 16.4.3 PROTECTIVE WRAPPING

Protective wrapping shall not be used indiscriminately. It shall be used only in locations as described below and shall not extend more than three inches or less than two inches on either side of the area of application. Wrapping shall be held in place by spot ties placed approximately 1/2 inch from each end and approximately three inches apart. Wrapping shall overlap sufficiently to prevent gapping. Figure 3 shows a typical installation using wrapping as a protective measure. If wrapping is used, it shall consist of non-adhesive approved sleeving or tape of proper width, applied around the harness. The wrapping material selected shall be of a type that will ensure complete harness protection for the intended use (i.e., protection against abrasion, heat, moving parts, etc.). The following criteria shall be used for selection of the applicable wrapping method and/or material:

- a. Sleeving or other approved chafe-guarding material shall be placed around the wire harness at any place where the bundle contacts or potentially contacts any other object that may chafe the bundle. Sleeving shall be used on each harness where two harnesses cross and are spot tied together, as well as in back of connectors with strain relief clamps.
- b. Wrapping tape may be used on wire bundles where moderate wear due to handling or other personnel contact may be encountered and where a relatively smooth unabrasive surface may be contacted. Wrapping tape shall not be used where two harnesses cross or when a harness lays near sharp abrasive surfaces.

#### 16.5 HARNESS INSTALLATION

Where possible, all wire harnesses shall be installed in the form of quickly removable and replaceable harnesses, attachable to and detachable from the adjacent harnesses, regardless of function, location, or form of electrical connection. All harnesses shall be installed so that installation or removal of equipment is permitted. Wire harnesses shall not be pulled to facilitate installation, nor to secure additional slack. Any visible evidence of damage to the harness is cause for rejection.

#### 16.5.1 ROUTING

All electrical wire harnesses shall be routed to avoid abrasion, cutting, or piercing of the outer insulation by contact with rough surfaces, sharp edges, or shockmounted equipment. Harness assemblies clamped to the structure shall be routed as directly as possible (insofar as practical harness assemblies shall be mounted parallel and/or perpendicular) and shall be protected along traffic lanes and near entrance areas where the harness is susceptible to use as handholds, steps, or other misuse. Wire harnesses may contact other harnesses provided they are suitably attached and routed to:

- a. Provide accessibility for inspection and maintenance.
- b. Prevent harness deterioration from high temperature or cold temperature extremes.
- c. Minimize possibility of damage.
- d. Minimize the need for protective material.

#### 16.5.2 ROUTING NEAR FLAMMABLE FLUID LINES

A separation of 2 inches shall be maintained between harnesses and lines carrying flammable fluids. Where barriers exist that preclude contact between harnesses and fluid lines, the requirements for separation and mounting shall not apply. Where necessity dictates a closer proximity, the harness shall be rigidly clamped and covered with protective insulating materials, but in no case shall fluid lines and harnesses be separated by less than 1/2 inch. Clamps may be attached as shown in Figure 4 to the flammable fluid line to prevent the harness from contacting the line, but these clamps shall not be used to support the harness.

#### 16.5.3 ROUTING NEAR NON-FLAMMABLE FLUID LINES

Where necessary due to structural characteristics, harness assemblies may be clamped to a nonflammable fluid line for separation. Installations shall be separated from nonflammable fluid lines by a minimum of 1/2 inch. Reference Figure 4.

#### 16.5.4 IMPROPER CONNECTIONS

Where similar connectors are used in adjacent locations, wire harnesses should be so routed and supported that improper connections cannot be made.

#### 16.5.4 IMPROPER CONNECTIONS (Continued)

When this requirement cannot be accomplished by routing, special markings or identification shall be provided to highlight proper connections.

#### 16.5.5 DIRECTION OF BREAKOUTS

When breakouts of harnesses are made at a support clamp, they will, where possible, be made in a direction away from the clamp-cushion wedge or clamp-mounting screw, as illustrated in Figure 5. If the harness must break out in both directions, care shall be taken to ensure that the wire/cable insulation will not be damaged by the metallic portions of the clamp. Reference Figure 6.

#### 16.5.6 BEND RADIUS

The minimum radius of bend for installed wire harnesses shall not cause wire or cable insulation disruption nor affect normal wire harness life or characteristics. The wire harness bend radius is measured as shown in Figure 7, and shall conform to the following minimum requirements:

- a. Optimum bend radius shall approach 10 times the outside diameter of the harness and the radius shall be maintained by appropriate clamps.
- b. The minimum bend radius for harnesses containing American Wire Gage (AWG) 10 or smaller wire/cable shall not be less than three times the diameter of the harness.
- c. Minimum bend radius for harnesses containing coaxial cable or AWG 10 or larger wire/cable shall not be less than six times the diameter of the harness.

#### 16.5.7 SLACK

Slack in wire harnesses between clamp installations shall be provided to avoid strain on wires/cables in the harness or connections. (Refer to Figure 8.) Slack shall be minimized in order to achieve a neat and orderly appearance of the installations, but sufficient slack shall be provided for the following purposes:

- a. To permit ease of maintenance, including connector coupling and uncoupling.
- b. To prevent mechanical strain on wires or cables, junctions, and harness supports.
- c. To permit movement of shock-and-vibration-isolated equipment.

#### 16.5.8 SLACK CONDITIONS

Slack shall not be so great that the harness, under its own weight, or under acceleration or vibration loads, contacts sharp or rough objects that might damage the harness. Movement of the harness by hand shall not cause the harness to touch any adjacent surface. Movement by hand is defined as applying sufficient forces to move the harness without visibly distorting or moving the mounting clamps, or causing the harness to slide within the clamps. A 1/4 inch distance shall be maintained between the harness and any adjoining structure. If the slack permits the harness to come within 1/4 inch of a sharp or rough object which could cause damage, one or more of the following shall be accomplished:

- a. Reduce slack
- b. Increase the distance from object
- c. Add additional support
- d. Add adequate protection to the harness and to the sharp or rough object to adequately protect the harness from damage.

#### 16.5.9 SLACK BETWEEN SUPPORTS

Slack between supports shall be as follows:

- a. For assemblies containing 0 through 4 AWG wire, slack shall be provided between clamps to avoid strain on harness, but shall not be greater than 1 inch (for every 15 inches of harness length) between support points.
- b. For assemblies containing all other size wire, slack shall be provided between clamps to avoid strain on harness, but it shall not be greater than 1/2 inch (for every 15 inches of harness length) between support points.
- c. To permit connector mating/demating, there shall be sufficient length or slack at the initial installation of the harness. The additional length shall be distributed throughout the length of the harness assembly not to exceed slack requirements of (a) or (b) above.
- d. Where there is relative motion between support points, the slack in the harness assembly span between those points shall be sufficient to prevent strain on the wiring or connector.

#### 16.5.10 EXCESS LENGTH

Harnesses shall not be routed solely for the purpose of removing excess length. All excess harness shall be distributed throughout the total harness length, but shall not exceed the slack requirements between supports as specified in paragraph 16.5.9.

#### 16.6 INSPECTION REQUIREMENTS FOR HARNESS INSTALLATION

Harness installation integrity shall be in compliance with all provisions of this document. Particular care shall be exercised to ensure such compliance prior to closeout of areas or where subsequent installations make inspection difficult.

CAUTION: Inspections performed to verify integrity of installation shall be accomplished by visual examination. Handling or movement of harnesses shall be minimized. Due care must be exercised to avoid possible damage to a critical installation.

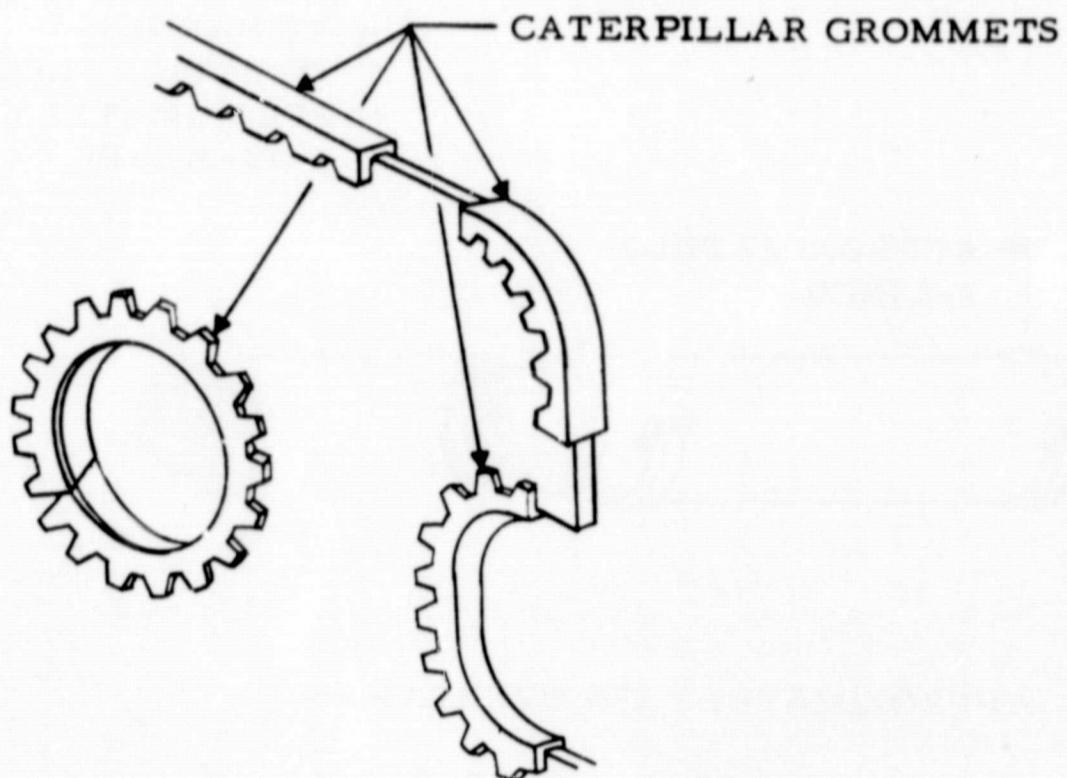


FIGURE 16-1 INSTALLATION OF CATERPILLAR GROMMETS

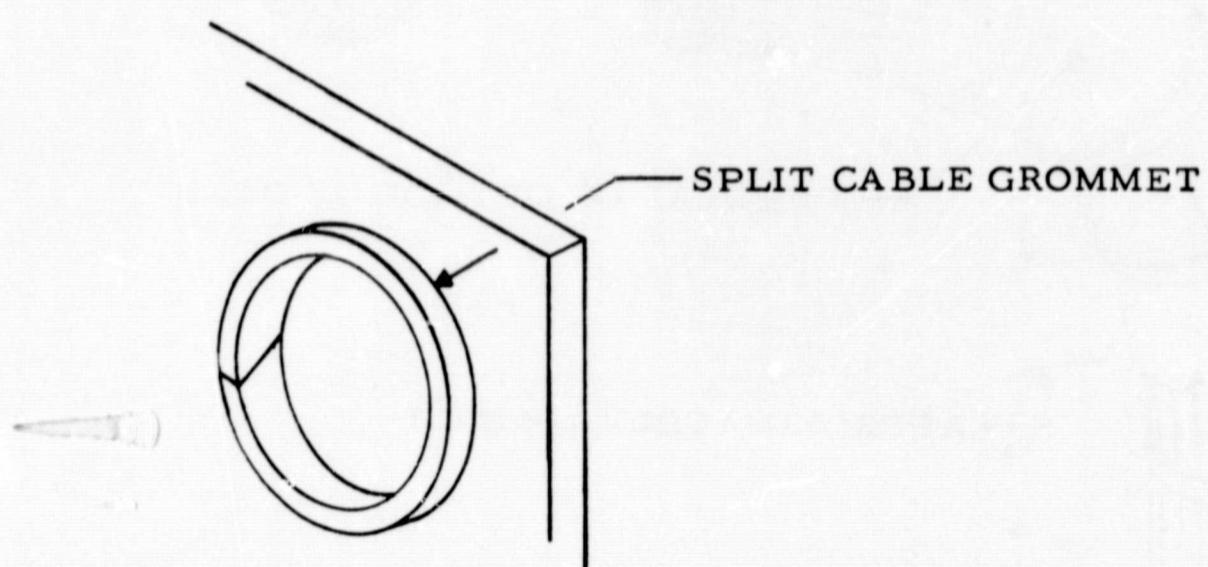


FIGURE 16-2 INSTALLATION OF SPLIT CABLE GROMMETS

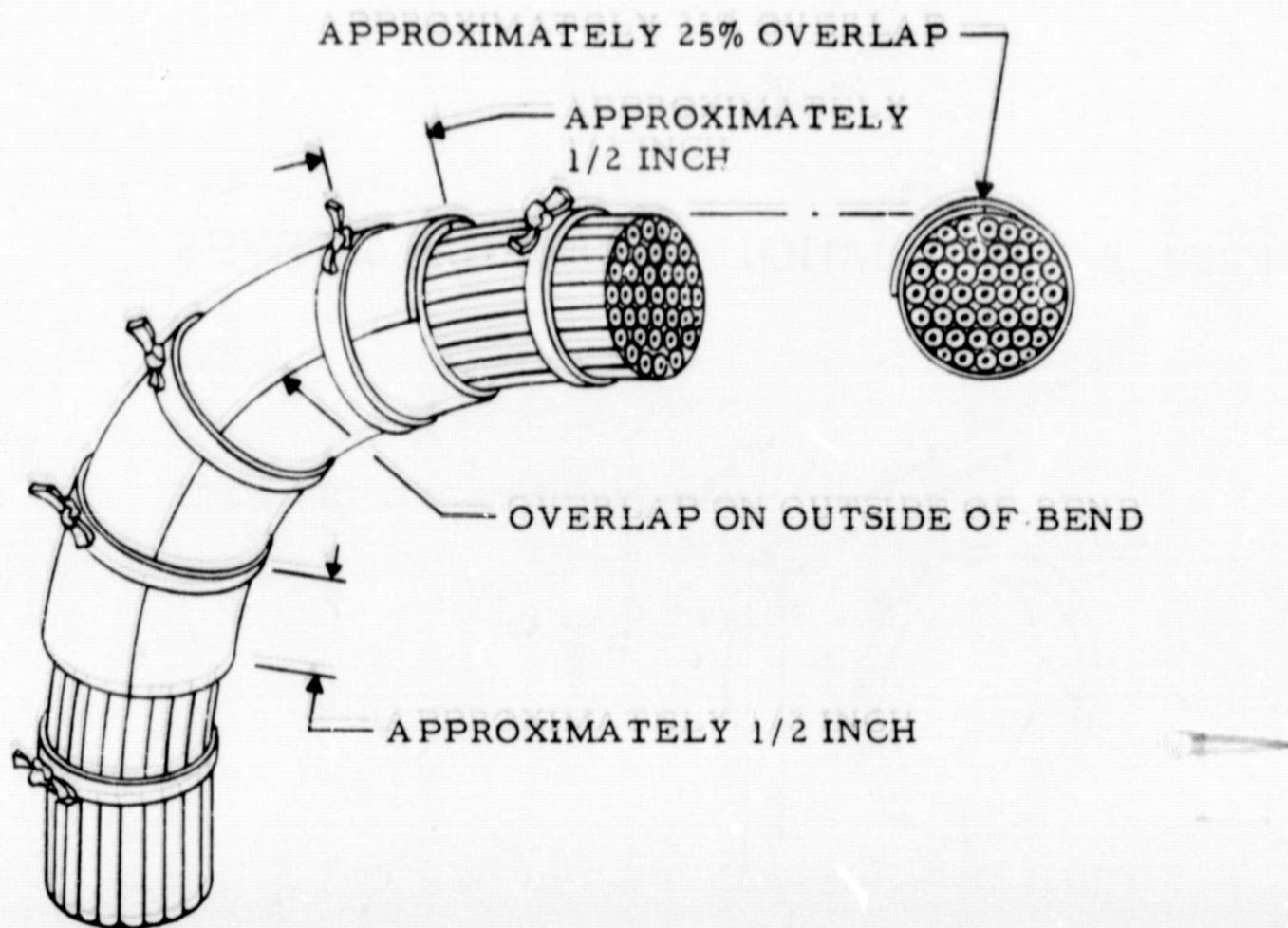
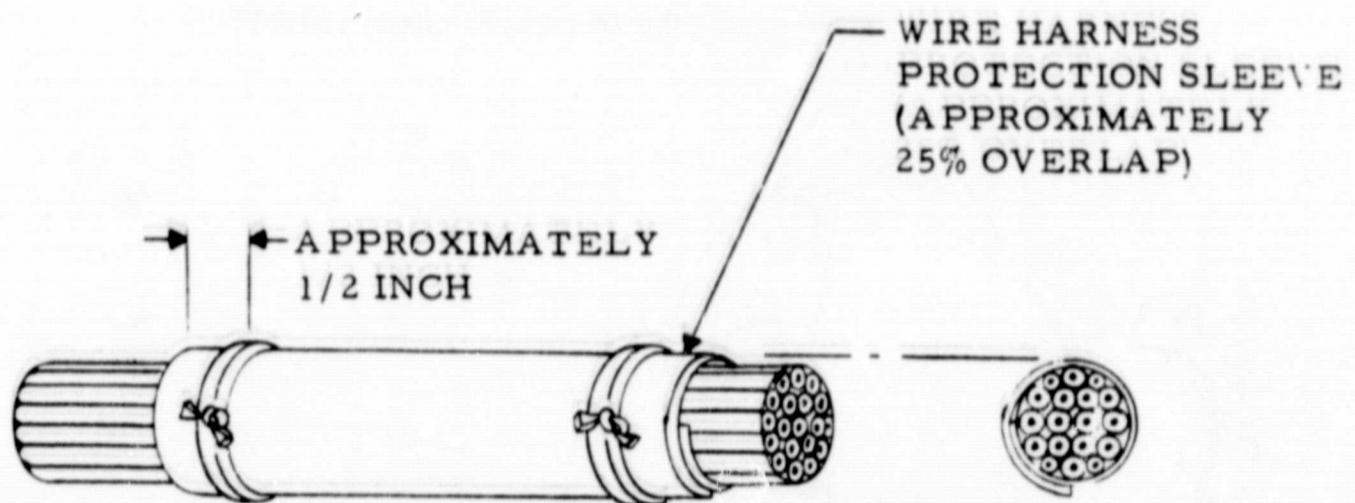


FIGURE 16-3 SPLIT SLEEVES AND SPOT TIES ON A WIRE HARNESS

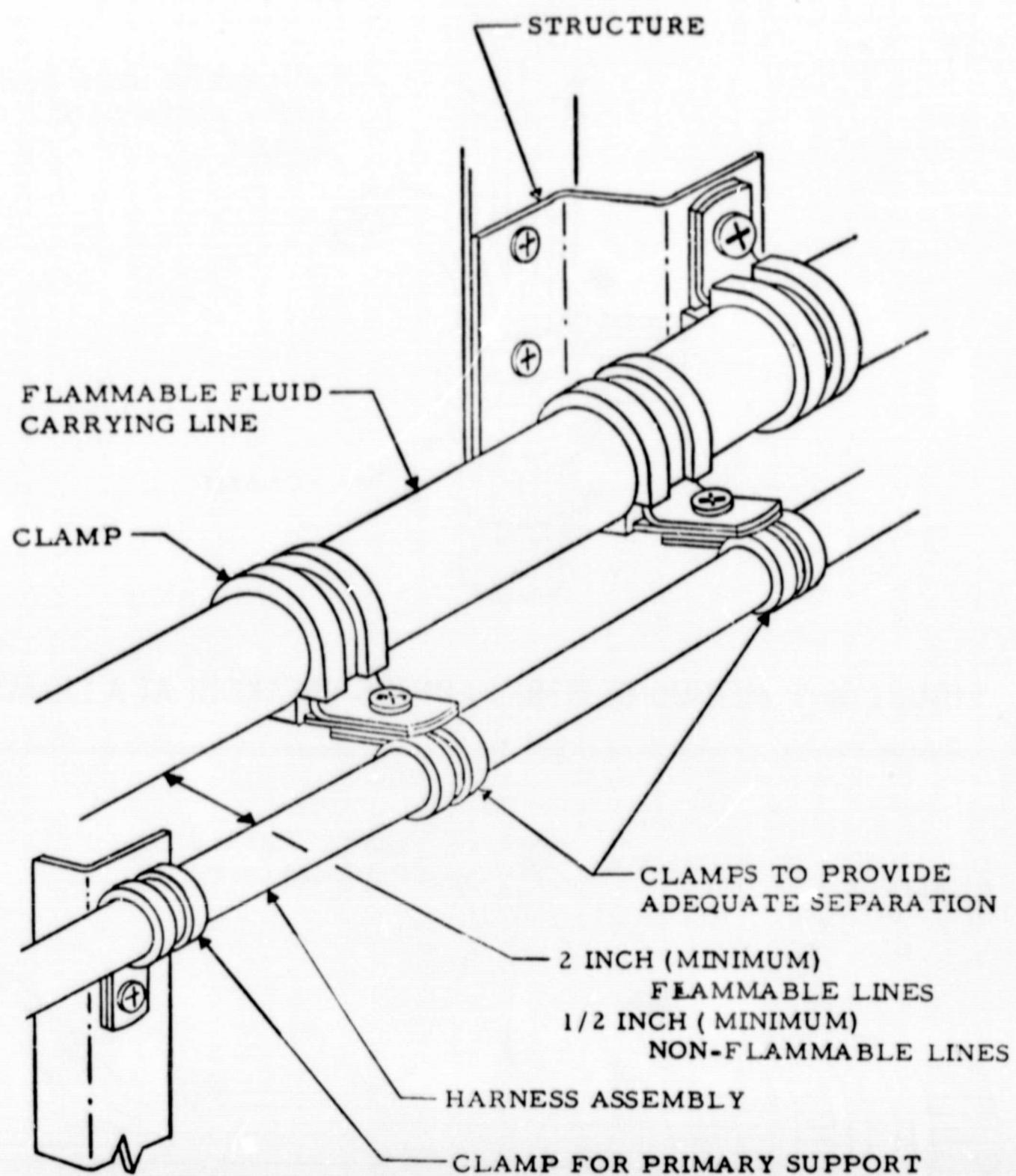


FIGURE 16-4 SEPARATION OF WIRE HARNESSES FROM FLUID LINES

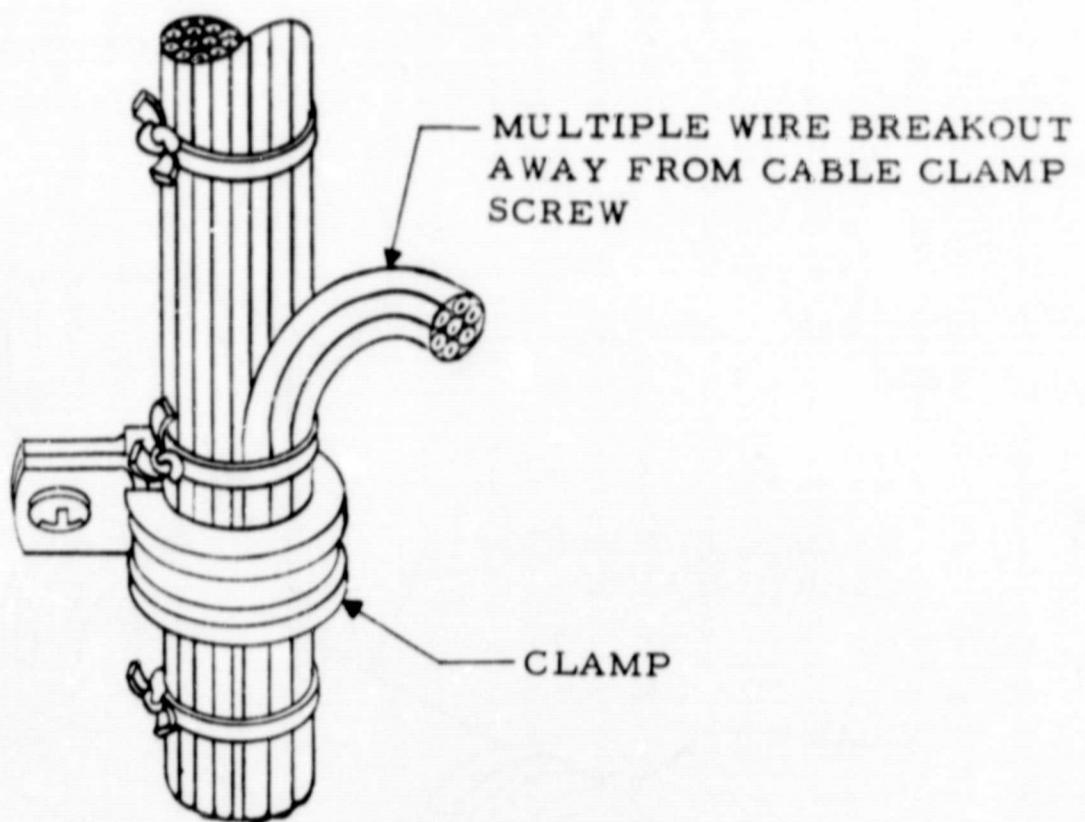


FIGURE 16-5 METHOD OF WIRE HARNESS BREAKOUT AT A CLAMP

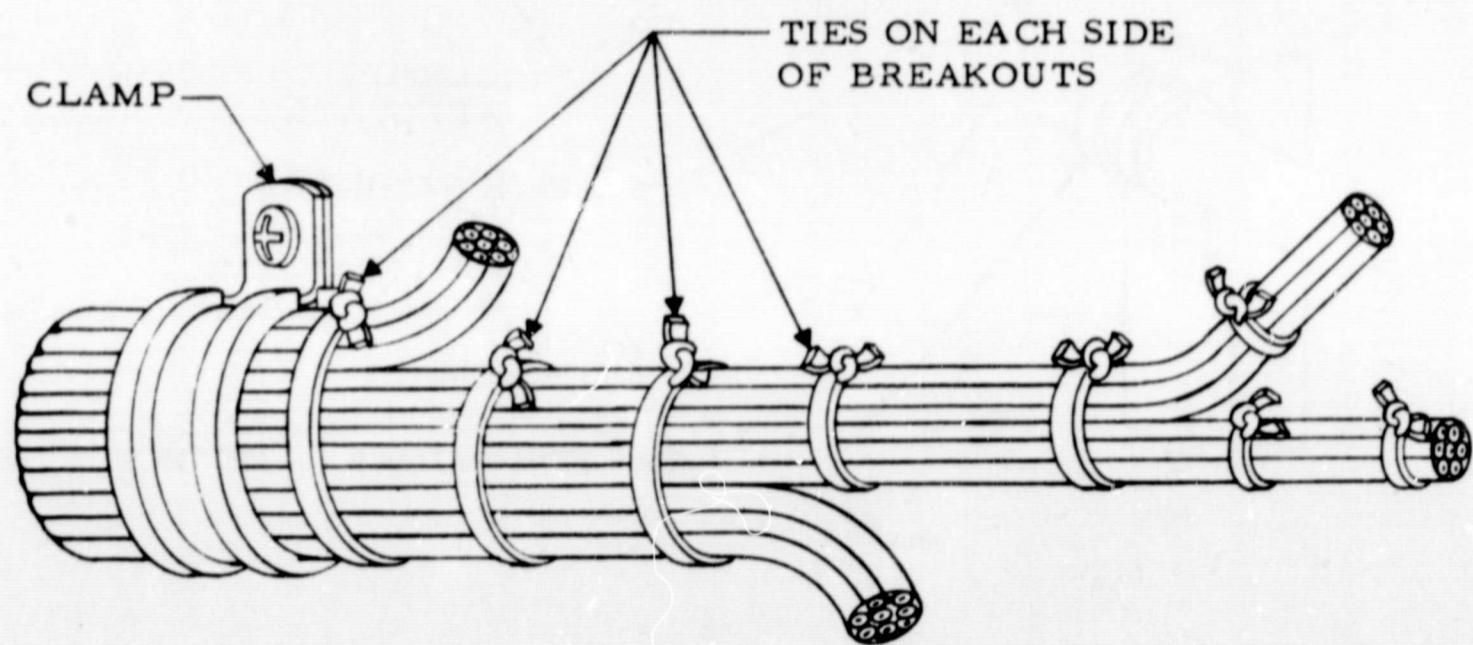


FIGURE 16-6 HARNESS WITH BREAKOUTS

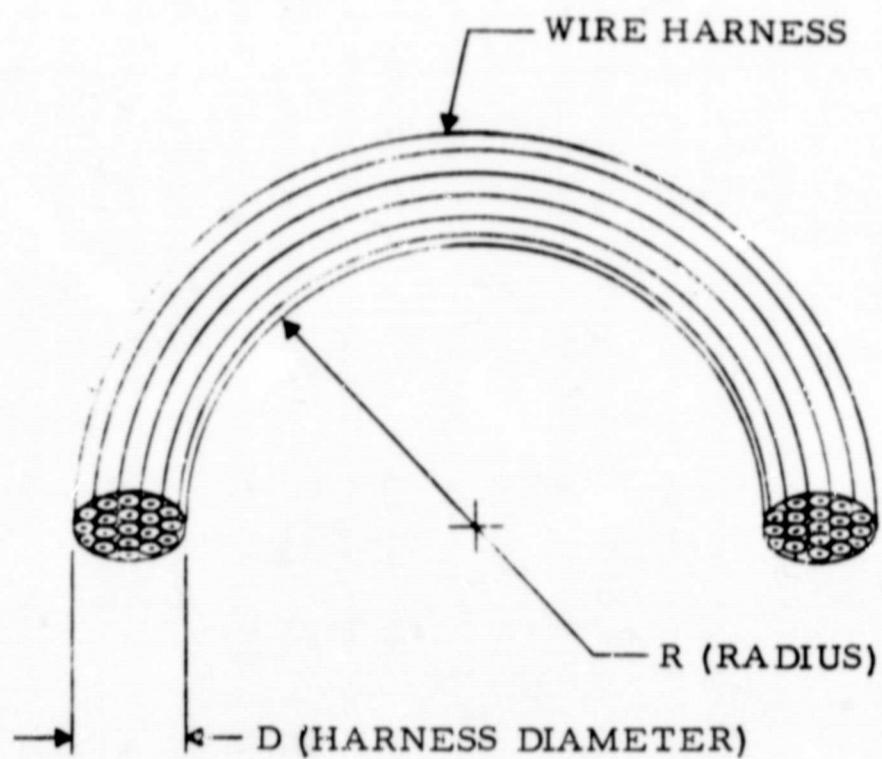


FIGURE 16-7 MEASURING BEND RADIUS

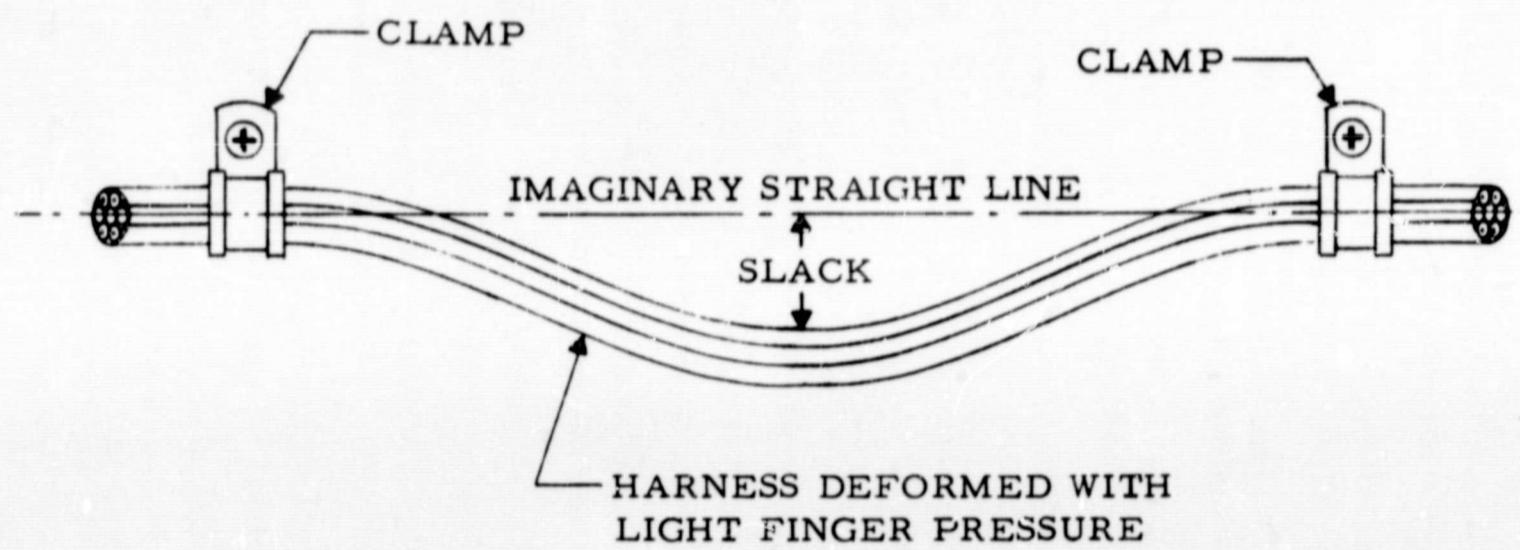


FIGURE 16-8 SLACK DEFINITION

SECTION 17  
SUPPORT AND CLAMPING

17.1 GENERAL

The primary purpose of the cushion-type clamp is to secure and support the wire harness. These clamps are also utilized to reduce or eliminate vibration, to maintain clearance, and to relieve strain on wire/cable terminating devices, shock/vibration mounts and other equipment. This section contains criteria relative to proper clamping techniques.

17.2 REQUIREMENTS

The standards, specifications, and engineering drawings that apply to installation of wire harnesses shall include the clamping requirements for proper harness support. When installing wire harnesses, utilizing approved clamping devices, the following criteria shall be considered:

- a. Prevention of chafing and migration within the support clamp.
- b. Provision of clearance when harnesses are routed through or adjacent to bulkheads or structural members.
- c. Maintenance of proper grouping during routing.
- d. Prevention of mechanical strain that would break wiring, cables, or connections.
- e. Prevention of excessive movement under vibration.
- f. Permit free movement of shock/vibration - mounted equipment.
- g. Prevention of interference between harnesses and other equipment.

17.2.1 TEMPORARY SUPPORT PROVISIONS

All wire harnesses shall be adequately supported during installation to prevent damage due to excessive bending, kinking, or strain. Such supports shall be of a type which will not cause cold flow of wire insulation. Temporary supports for harness connections shall not cause distortion of the wire entry holes in the rear face of the environmental sealing grommet or otherwise result in deterioration of the environmental seal.

### 17.3 CLAMPING DEVICES

In the fabrication and installation of harnesses, cushion-type clamps shall be used for harness support. Clamping devices shall be of suitable size and type to hold the wires/cables firmly without damage after fastening and without changing the cross-sectional shape of the bundle.

#### 17.3.1 CLAMP TYPE SELECTION

Wire harnesses shall be supported by clamps as specified on the applicable installation drawing. To insure proper fit, it is recommended that provisions be made to allow deviation of cushion clamp sizes larger or smaller than specified on the installation drawing. Loop clamps or saddle type clamps, as illustrated in Figure 1, may be used on wire harnesses not exceeding 2 inches in diameter, but all harnesses over 2 inches in diameter shall be supported by saddle-type clamps. In addition, the following criteria shall be used in selecting clamps:

- a. The size of the clamp shall permit the mounting tabs of the clamping device to meet without deforming the wire harness.
- b. The harness shall never contact the bare metal of the clamping device.
- c. Washers or other spacer devices shall not be installed between the mounting tabs of the clamping device to obtain proper fit.
- d. Deformation of the clamp or the clamp cushion material shall be cause for rejection.
- e. Clamps shall be of sufficient size that the harness is held firmly without the need of wrapped sleeving or tape, or the use of filler materials.
- f. Clamp size shall be adequate to hold the harness securely in position without being pinched or damaged.
- g. Clamping device shall have sufficient grip to prevent sliding or twisting of the wire harness inside the clamp after tightening to the point of gap closure between mounting tabs.

#### 17.3.2 WIRE/CABLE INSTALLATION

Whenever a cushion-type clamp is installed to support a harness, the entire harness must be contained within the cushioned part of the clamp. The wires/cables shall not cross under the clamp or be wedged between the mounting tabs of the clamp. Cable shield terminations shall be located so there will

### 17.3.2 WIRE/CABLE INSTALLATION (Continued)

be no interference with clamping of the wire harness and must not be installed in clamps or other harness supports. Spot-ties and tie wraps shall not be located under clamps.

## 17.4 CLAMP AND SUPPORT INSTALLATION

Harness assemblies supported by cushion-type clamps shall be secured to the vehicle structure. When harnesses are routed over or through structural members that have grommets, or any other protrusions and sharp edges, the harness shall be supported by clamping to prevent the possibility of chafing. Where necessary, due to structural characteristics, harness assemblies may be clamped to harnesses or nonflammable fluid lines for separation (minimum of 1/2 inch between). Clamping and securing of harnesses to pressure or flammable fluid lines shall not be permitted.

### 17.4.1 LOCATION

Normal harness runs shall be supported by clamps at intervals of not more than fifteen inches. The location of clamp devices shall ensure harness support against vibration, chafing, or general harness damage, and shall be sufficient to maintain the desired harness installation configuration. The following criteria shall be used as a basis for nominal clamp spacing:

- a. The distance between the first clamp and the back of the connector potting and/or backshell shall be no greater than 15 inches.
- b. Harnesses shall be supported at intervals not to exceed 15 inches.
- c. Ground wires shall be clamped a maximum of 3 inches from the ground termination point.
- d. Where harnesses are routed through or over grommets, the harness shall be supported by clamping as close as practical to the grommet.

### 17.4.2 MOUNTING OF CLAMPS

Support clamps shall be firmly secured and installed at right angles to the wire harness to minimize the possibility of abrasion from edges of clamps. Single loop cushion clamps shall be installed with the attachment above the harness whenever possible. All supporting clamps shall be secured to the attaching point and torqued to the recommended value stated on the applicable engineering drawing or specification.

## 17.5 INSPECTION REQUIREMENTS FOR CLAMPING WIRE HARNESES

Wire harness clamping devices shall be of suitable size and type to hold the harness firmly, without damage after fastening. The size of the clamp shall permit the mounting tabs of the clamping device to meet without deformation. (Reference Figure 2.)

### 17.5.1 INSPECTION OF WIRING SUPPORTS

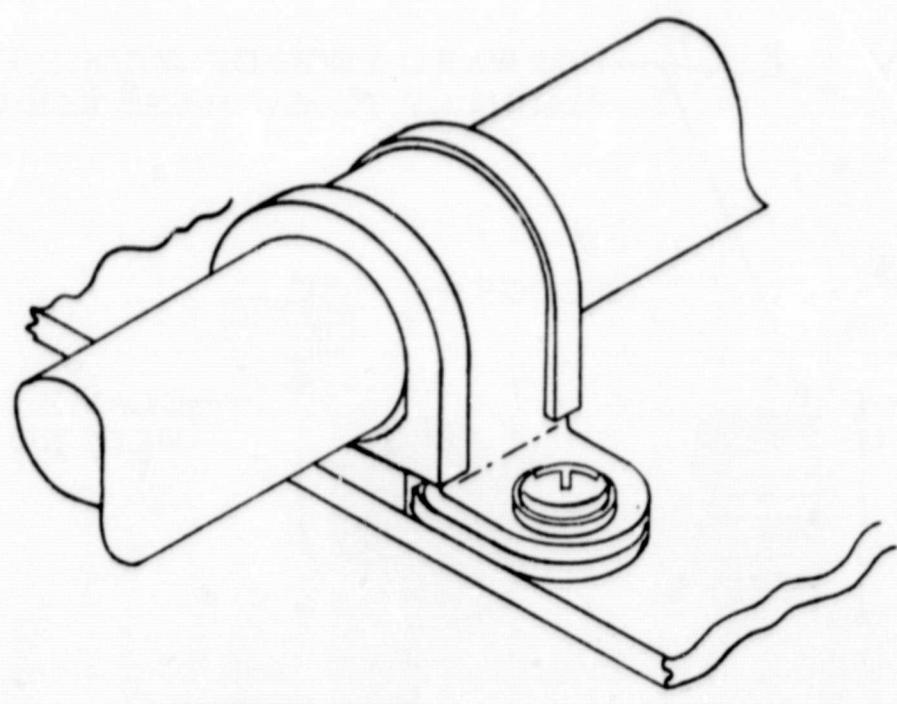
When inspecting for proper wiring support, the following unacceptable conditions shall also be considered:

1. Harnesses supported by any fluid line (gas or liquid) or wire spacing support that is fastened to a fluid line.
2. Wiring clamps, bonding jumpers, or electrical terminations installed under primary structure fasteners.
3. Spot ties that are used as primary support for wiring.
4. Spot ties, tie wraps, sleeving, or other materials on bundles located between mounting tabs on cable clamps.
5. Cable clamps deformed or bent.

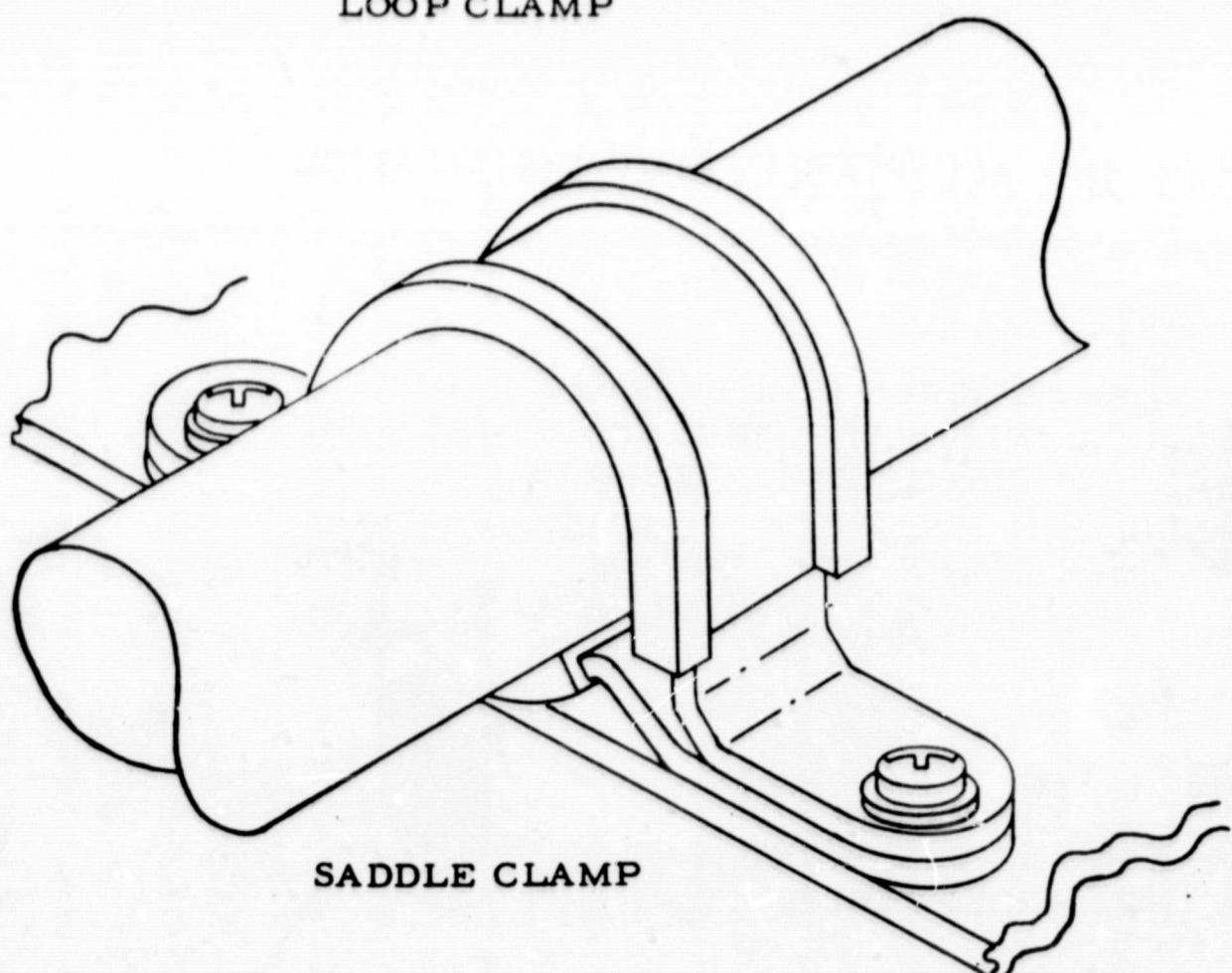
(Reference Figure 3.)

### 17.5.2 CUSHION DAMAGE

Inspect clamp cushion material for unacceptable conditions such as cuts, gouges, or wire insulation contacting the metal surface of the clamp assembly. Slight abrasions and minor imperfections of the cushion material will be acceptable. (Reference Figure 4.)



LOOP CLAMP



SADDLE CLAMP

FIGURE 17-1 EXAMPLE OF LOOP CLAMP AND SADDLE TYPE CLAMP

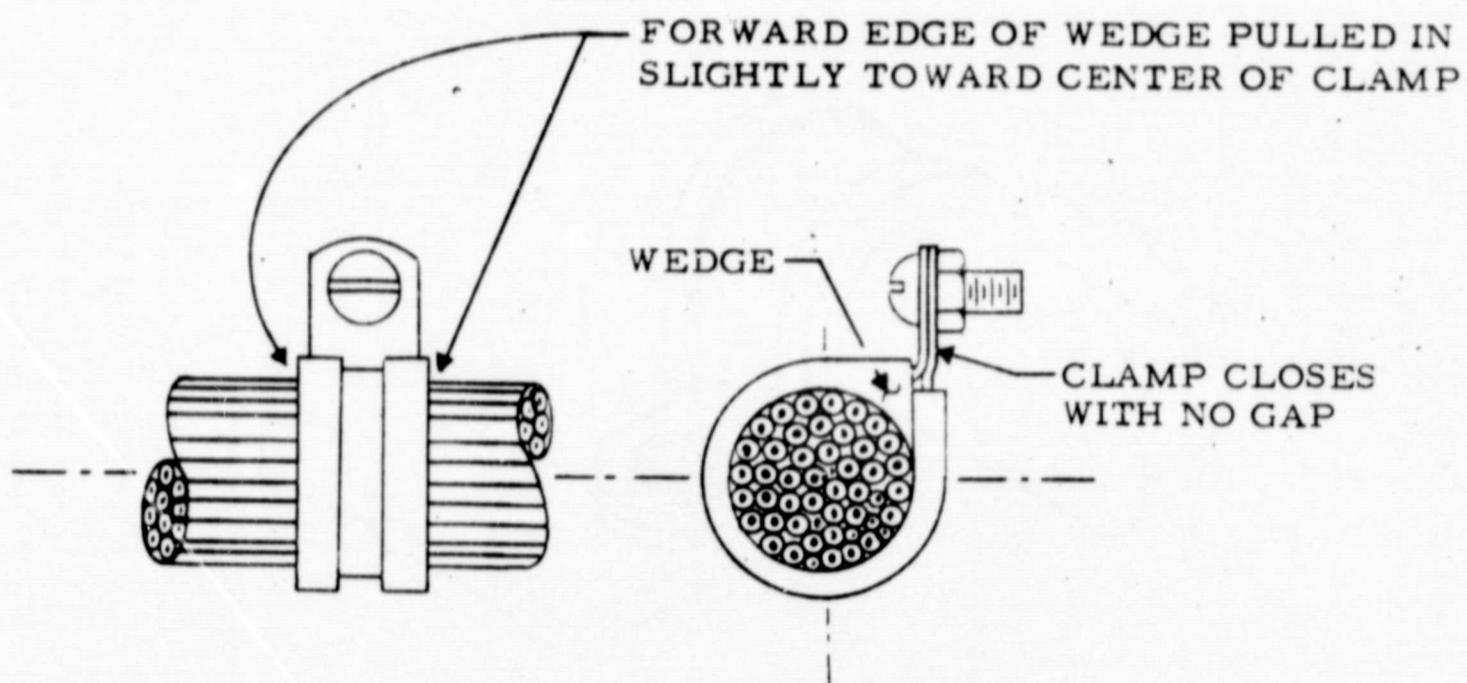


FIGURE 17-2 ACCEPTABLE CLAMP INSTALLATION

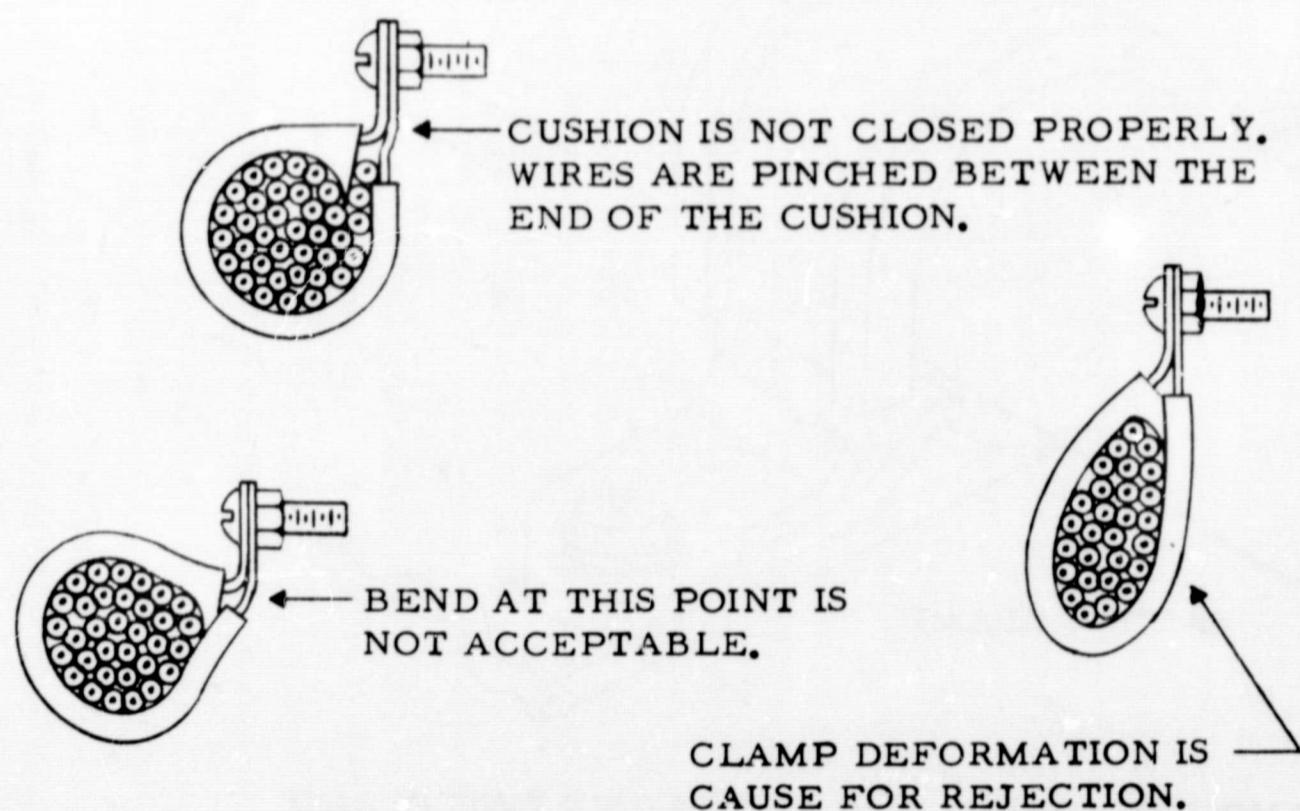
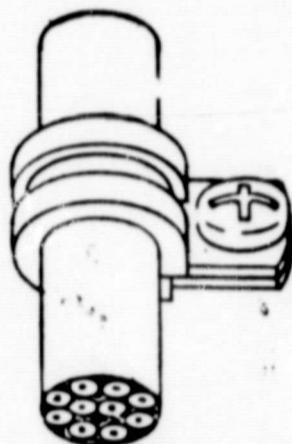
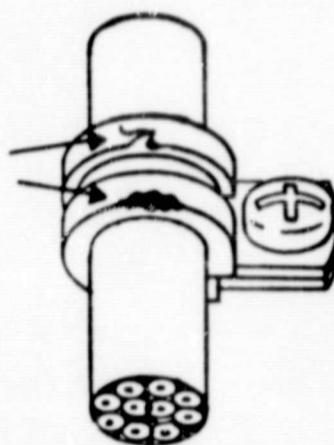


FIGURE 17-3 UNACCEPTABLE CLAMP INSTALLATION



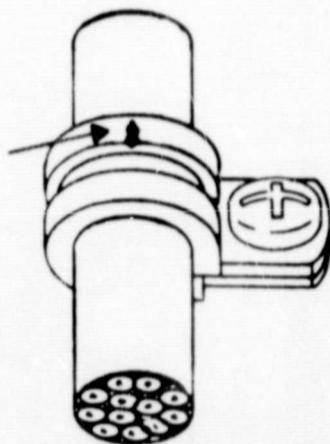
THE RUBBER CUSHION SHALL BE FREE FROM GOUGES THAT EXPOSE THE METAL CLAMP, AND FROM CUTS OR CRACKS RUNNING PARALLEL TO THE WIRE HARNESS.

ACCEPTABLE



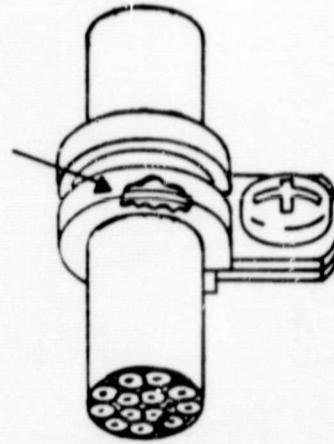
SLIGHT ABRASIONS AND MINOR IMPERFECTIONS (ARROWS) ARE ACCEPTABLE PROVIDED THERE IS NO EXPOSED METAL OR SHARP INDENTATIONS WHICH MAY DEVELOP INTO CRACKS.

ACCEPTABLE



CUSHION IS WEAKENED BY CUT (ARROW) RUNNING PARALLEL TO THE WIRE HARNESS. CUT WILL TEND TO PROPOGATE AND INCREASE CUSHION SEPARATION.

UNACCEPTABLE



THE METAL CLAMP HAS BEEN EXPOSED BY A GOUGE (ARROW).

UNACCEPTABLE

FIGURE 17-4 CLAMP, SINGLE LOOP-CUSHION DAMAGE

SECTION 18  
CONNECTOR MATING

18.1 GENERAL

This section establishes the standard processes related to mating of electrical connectors. The criteria contained in the following paragraphs shall apply to all types of connectors, except where noted.

18.2 PROCESS CONTROL REQUIREMENTS

Immediately prior to mating, visually examine each connector to ensure that:

- a. The insert faces are clean and free of chips, dirt, or any foreign materials that would damage the pins, or that would prevent them from easily entering the socket.
- b. There are no bent, damaged, or misaligned pins or sockets or any splits, cuts, gouges, or other damage to the grommets.
- c. The pins or sockets are not abnormally recessed or extended.
- d. There are no nicks or fractures in the connector shell or inserts.
- e. The plating is free of flaking, porosity, roughness, or non-adhesion.
- f. Connectors with removable "o" ring seals or grommets are properly installed in the connector halves prior to mating.
- g. Connectors are properly marked so that "P" and "J" numbers match, and pin and socket configurations are compatible.

18.2.1 CONNECTOR PROTECTION

All connectors shall have protective caps installed throughout all stages of fabrication and installation, except when mated. The caps shall provide both environmental and physical protection.

**NOTE:** Protective caps on the connectors may be removed during the visual examination, but must be re-installed and remain in place until the connectors are ready to be coupled.

18.2.2 PRECAUTIONARY PROCEDURES

Caution shall be exercised when mating connectors to ensure that damage does not occur to connector pins or sockets. Under no conditions shall

#### 18.2.2 PRECAUTIONARY PROCEDURES (Continued)

connectors be subjected to undue manual force during the installation process. In addition, the following precautionary procedures shall be adhered to:

- a. There shall be adequate wire length for bundle flexing during connector coupling and uncoupling.
- b. Wire harnesses (excluding coaxial cables) shall not be twisted more than 1/4 turn between connector and the first clamp to align connector keyways, and should an additional 1/4 turn be required, this required twist must be made between the other support clamps. Coaxial cables shall not be twisted during mating operations.
- c. Wire bundles shall not be pulled to obtain the required length needed to complete mating of connectors. Appropriate slack between the connector and first clamp shall be assured prior to connector mating.

#### 18.3 CONNECTOR MATING

During mating operations, the connector coupling devices shall be closely monitored visually, audibly, and by feel to ensure that proper mating has been accomplished. Mating procedures for four major types of connectors are covered in this section; (1) the bayonet type which has three ball-locks in the receptacle that engages the coupling ring; (2) the push-pull type which has a ball-lock coupling ring; (3) the threaded coupling ring type; and (4) the rectangular type which secures with jack screws.

##### 18.3.1 BAYONET TYPE CONNECTOR INSTALLATION

Secure bayonet lock type connectors only by hand. When bayonet type plugs and receptacles are to be mated, the following procedure shall be used, in conjunction with Figure 1:

- a. Align the receptacle keyways with the plug keys.
- b. Rotate coupling rings clockwise so that the engagement pins on the receptacle shell are positioned into the inner grooves of the coupling ring.
- c. Continue rotation until engagement pins snap into view through the indicator holes. Color coding (if applicable) on the coupling ring shall be aligned with corresponding code on the receptacle.

#### 18.3.2 PUSH-PULL TYPE CONNECTOR INSTALLATION

When push-pull type plugs and receptacles are to be mated, align the key-way on the plug with the key on the receptacle. Push forward, exposing the colored ring which indicates engagement. (Reference Figure 2.)

#### 18.3.3 THREADED COUPLING TYPE CONNECTOR INSTALLATION

The threaded type connector employs a single key-slot in the receptacle and a corresponding key in the plug to ensure proper plug to receptacle orientation prior to engagement of the threaded coupling ring. Connector clocking is accomplished by the position of the insert within the connector shell (Reference Figure 3). Following alignment of the connector key, the connector shall be tightened as described in paragraph 18.4.

#### 18.3.4 RECTANGULAR TYPE CONNECTOR INSTALLATION

Electrical rectangular connectors shall be carefully mated and unmated in accordance with the following:

- a. Place the mating connector carefully in position by aligning the polarizing keys (posts) with the mating key slots and align the jack screws with the threaded bore in the coupling side. Do not rock plug side to side during mating or unmating.
- b. Tighten the jack screws alternately until each jack screw is bottomed on the coupling. Turn each jack screw no more than 2 turns each, alternately. Unequal tightening of the jack screws will result in damage to the connector or contacts.
- c. Torque each jack screw to the required level.
- d. Safety wire jack screws to connector flange in accordance with MS33540. The safety wire shall be installed such that the wire insulation in each connector will not be touched or possibly damaged by the safety wire. (Reference Figure 9.)

#### 18.4 TIGHTENING CONNECTORS

Connectors with threaded couplings shall be tightened, as far as travel permits, by hand to permit proper alignment and prevent damage to threads. Torquing shall then be accomplished if required. Jam nuts of jam nut type receptacles shall be torqued in accordance with Table 1. The coupling nut of screw type connector shall meet the requirements of Table 2.

#### 18.5 SAFETY WIRING

Safety wire shall be applied so that the connector will not loosen. To achieve a pulling effect, the safety wire shall not be in-line with the center of either connector, but shall be pulling in a tightening direction with respect to the two points where the wire is fastened. Refer to Figures 4 through 8, for illustrations of acceptable, typical safety wiring methods. The safety wire shall be installed with the double twist method and shall have 6-14 twists per lineal inch. The tag ends of the wire shall have 3 to 6 twists and shall be neatly trimmed to a length of approximately 1/2 inch. The tag ends shall be bent back against the connector to avoid snagging or scratching any object. The final installation of safety wire shall be correctly positioned with sufficient tension so that the wire cannot be moved or slid in any direction which could permit the threaded parts of the connector to loosen. The wire shall have the shortest possible length. Various acceptable methods for installing safety wire on connectors are shown in figures 4 through 9.

#### 18.6 QUALITY CONTROL SEALING

Quality control seals shall be installed after the connector has been mated, torqued, and safety wired (if required) according to the applicable drawings. Quality control seals will be installed in such a manner that the coupling ring cannot be disengaged without breaking the seal. Connectors with broken seals shall be subjected to a thorough reinspection to assure connector integrity, and then resealed. The seals and the environment in which they are used shall be compatible.

Table 18-1. Jam Nut Torque Values

Connector Shell Size	Torque, Foot-Pounds	
	Minimum	Maximum
8	2.2	2.5
10	2.7	3.0
12	3.6	4.0
14	4.5	5.0
16	5.4	6.0
18	6.3	7.0
20	7.2	8.0
22	8.1	9.0
24	9.0	10.0
36	13.5	15.0
40	15.3	17.0

Table 18-2. Coupling Nut (Screw Type Connector)

Connector Shell Size	Torque, Foot-Pounds	
	Minimum	Maximum
10	2.2	2.5
14	3.6	4.0
20	6.3	7.0
24	8.1	9.0
28	9.9	11.0
32	11.7	13.0
40	15.3	17.0

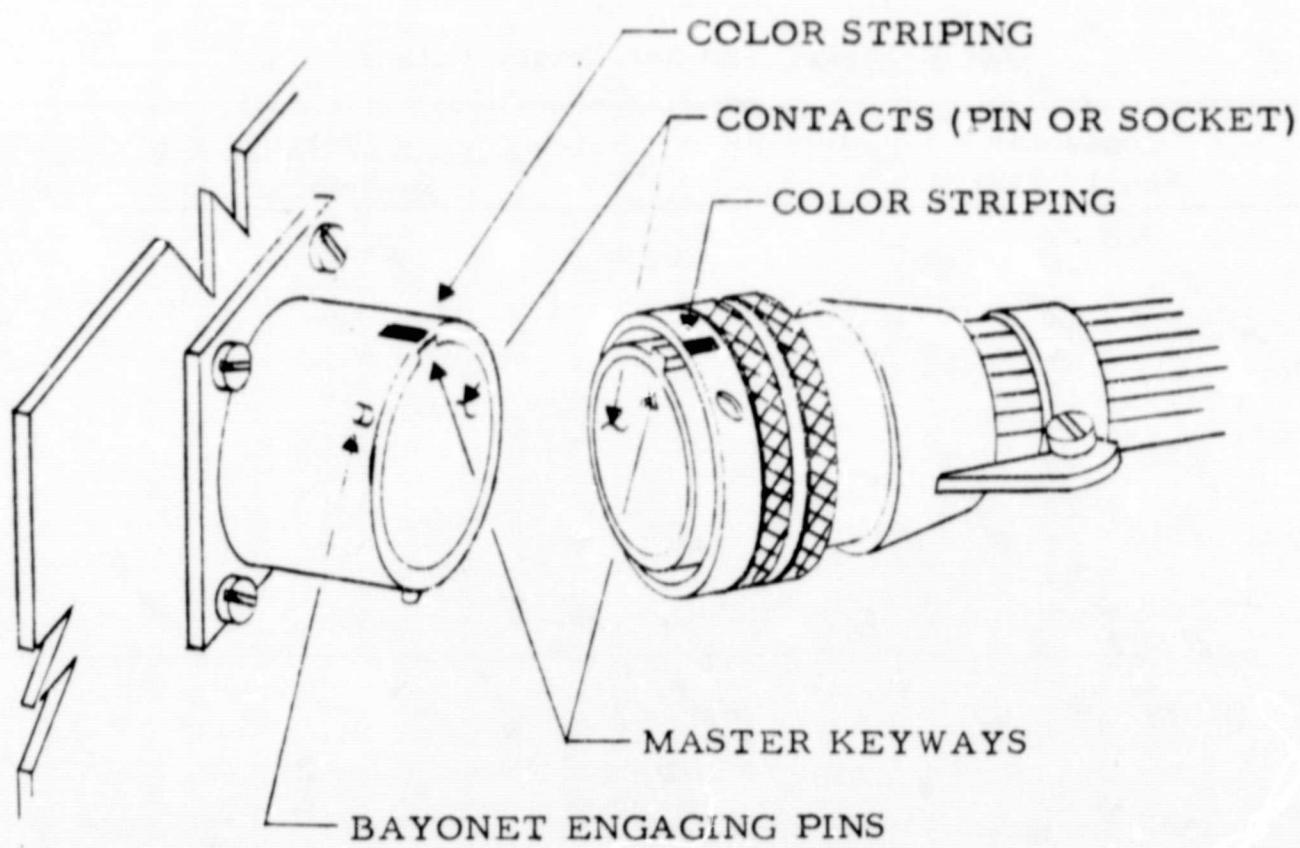


FIGURE 18-1 BAYONET COUPLING

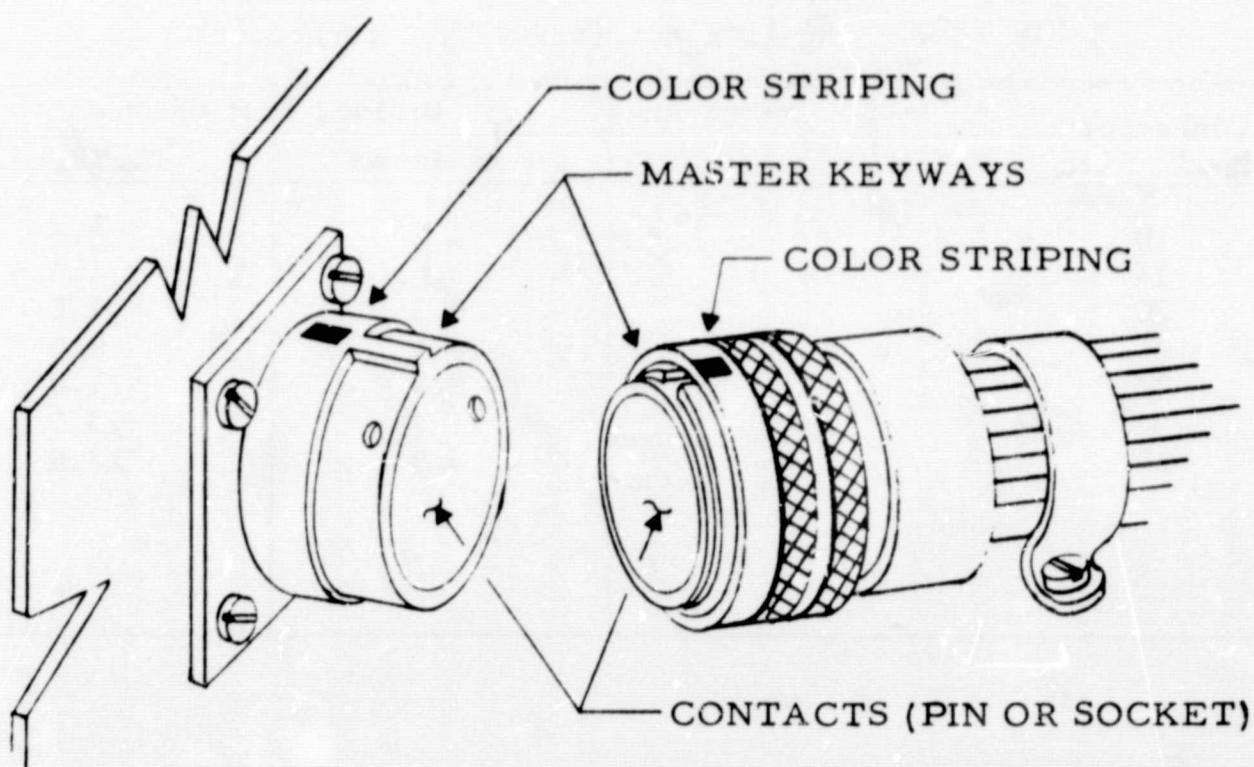


FIGURE 18-2 PUSH-PULL COUPLING

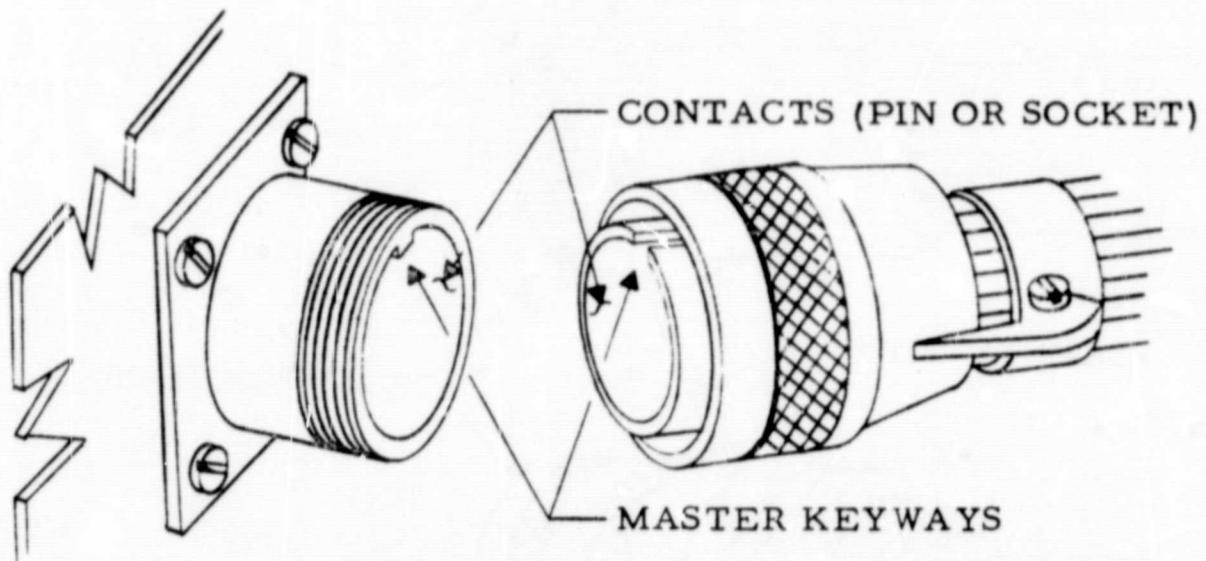


FIGURE 18-3 THREADED COUPLING

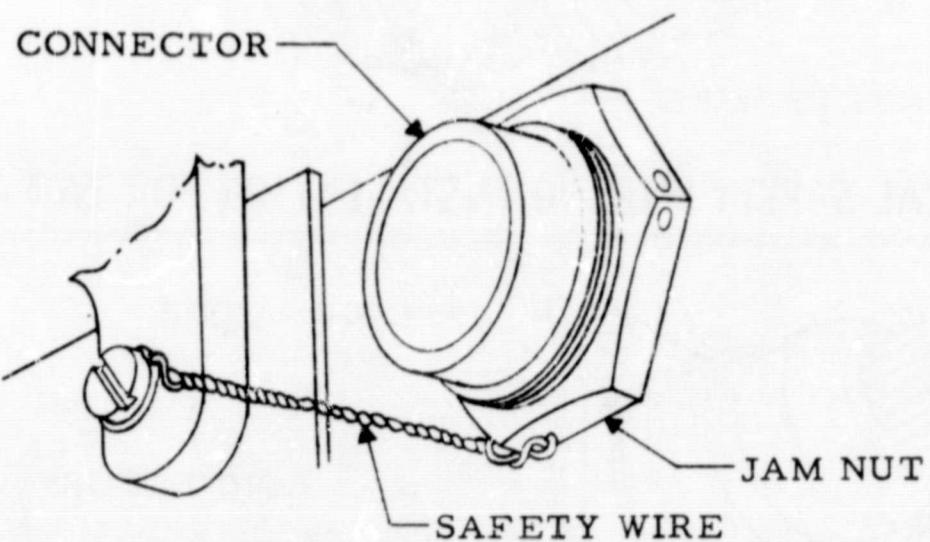


FIGURE 18-4 SAFETY WIRE ON A JAM NUT

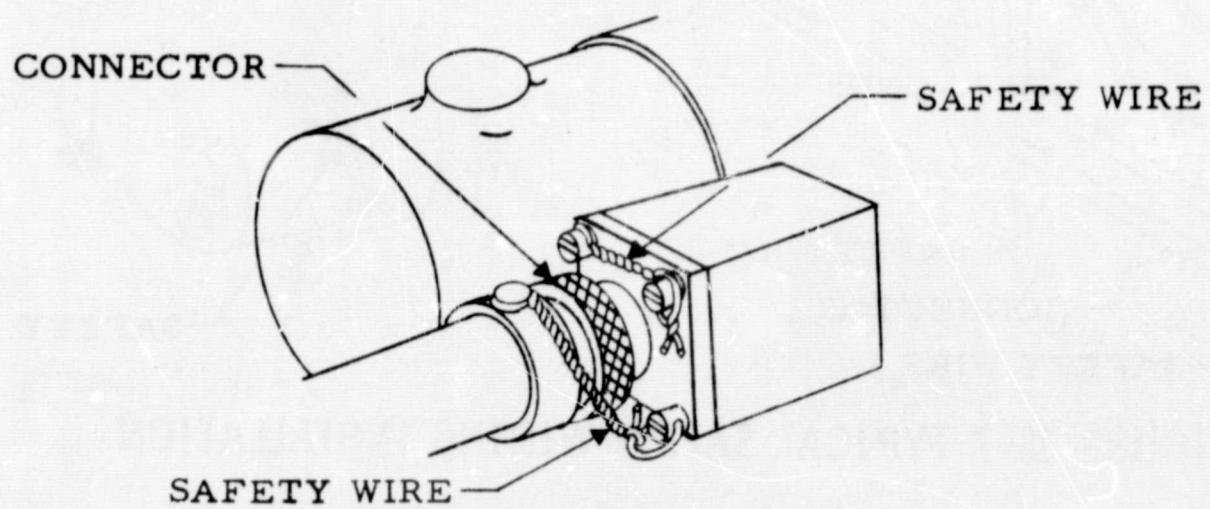


FIGURE 18-5 TYPICAL SAFETY WIRING INSTALLATION

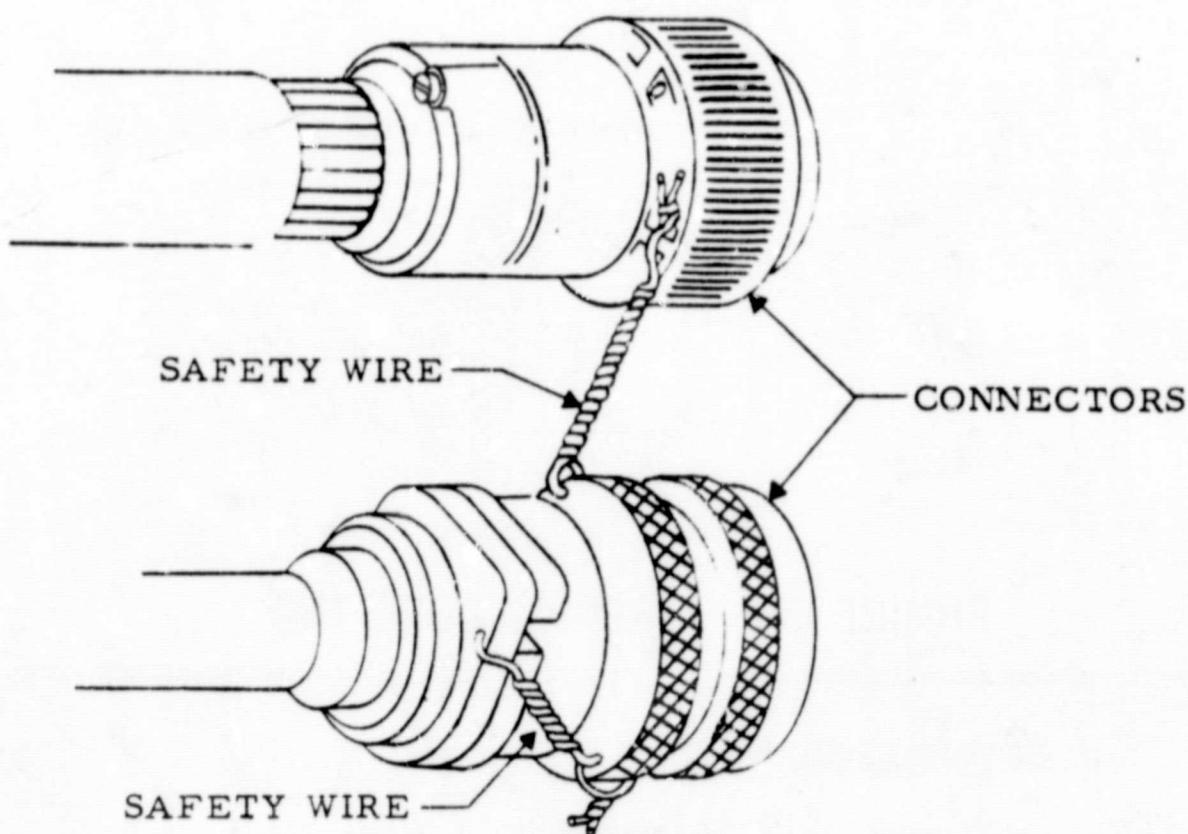


FIGURE 18-6 TYPICAL SAFETY WIRING INSTALLATION FOR TWO CONNECTORS

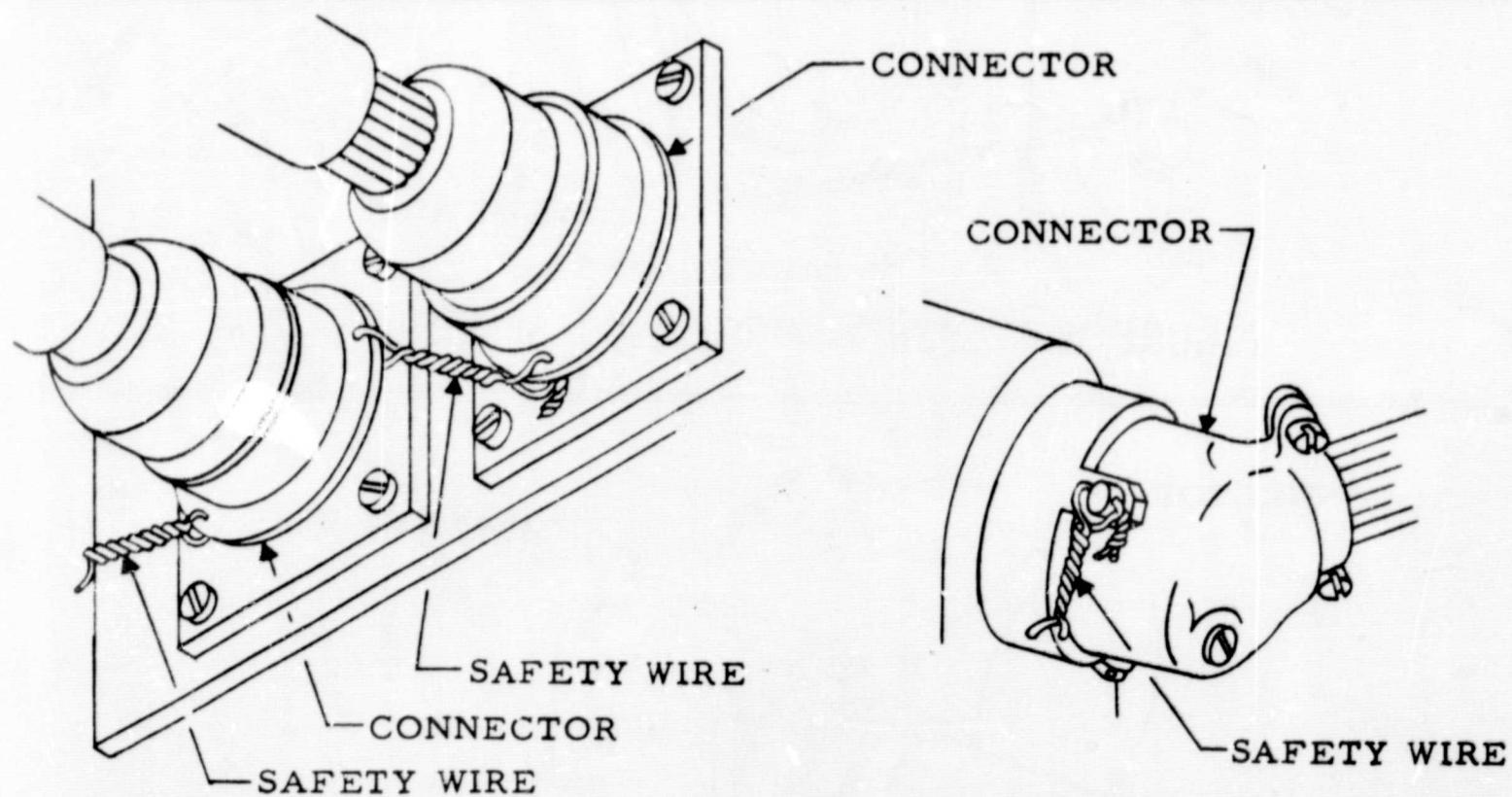
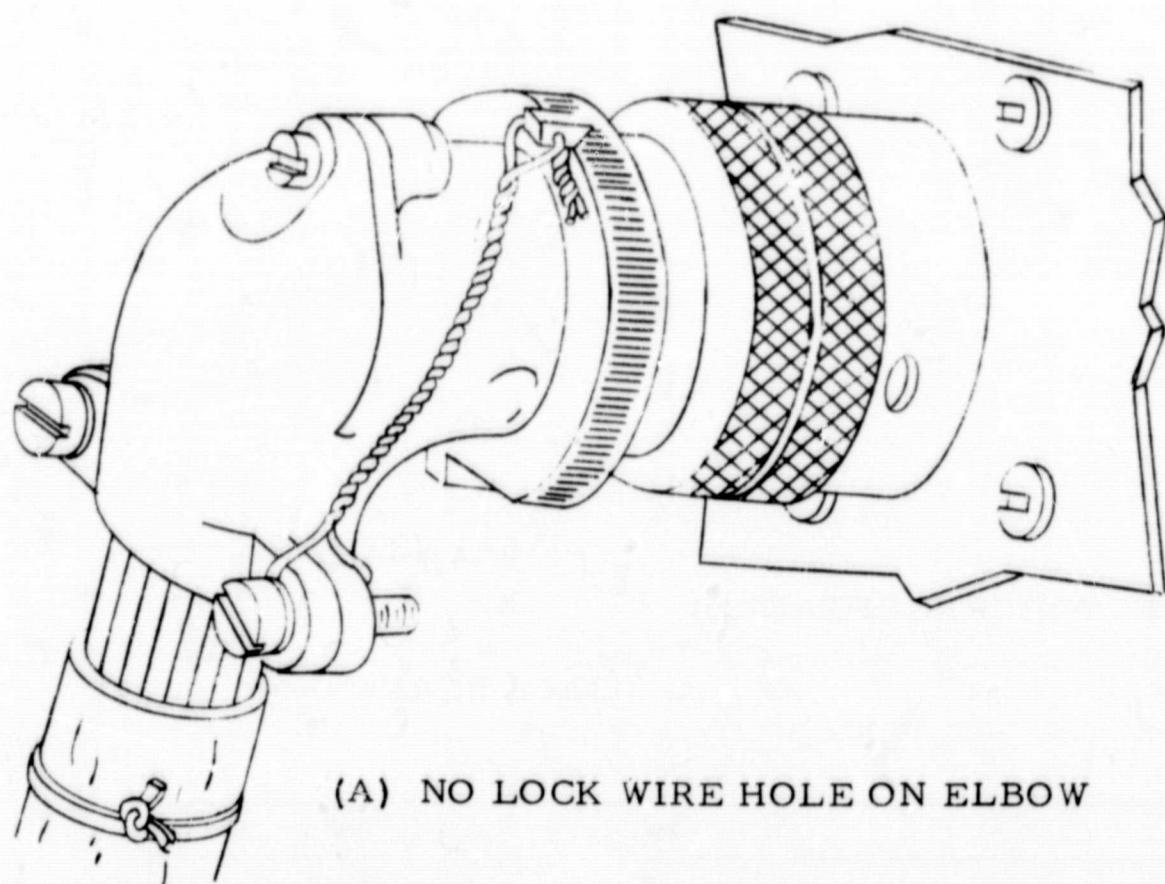
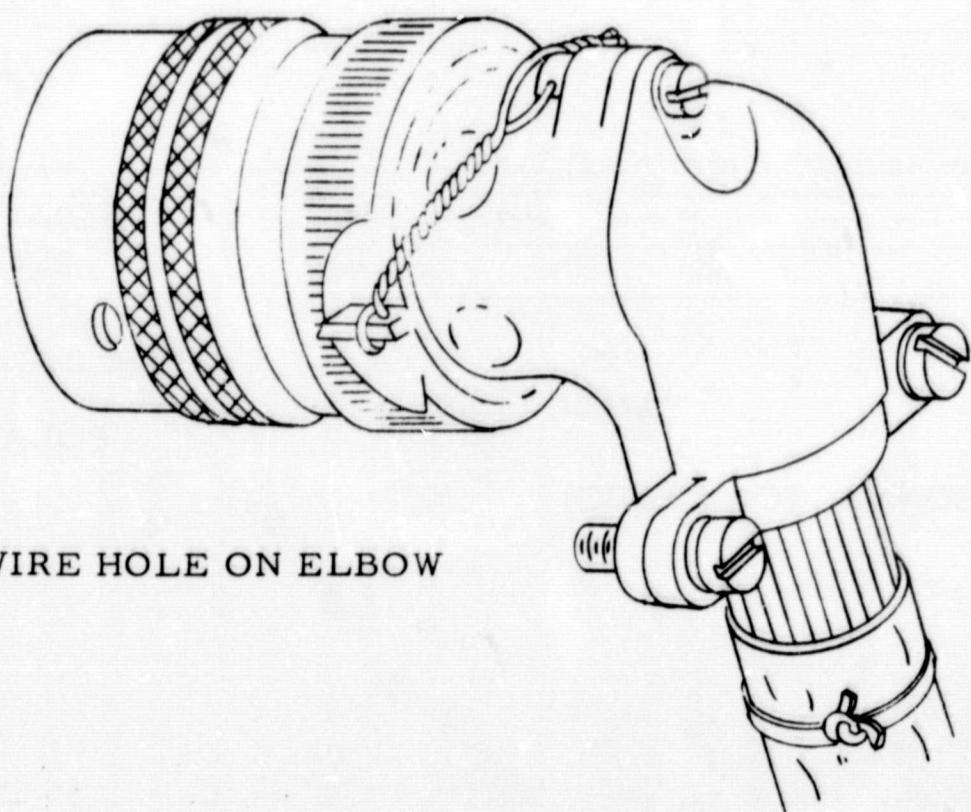


FIGURE 18-7 TYPICAL SAFETY WIRING INSTALLATION



(A) NO LOCK WIRE HOLE ON ELBOW



(B) LOCK WIRE HOLE ON ELBOW

FIGURE 18-8 TYPICAL SAFETY WIRING INSTALLATION FOR ELBOW CONNECTORS

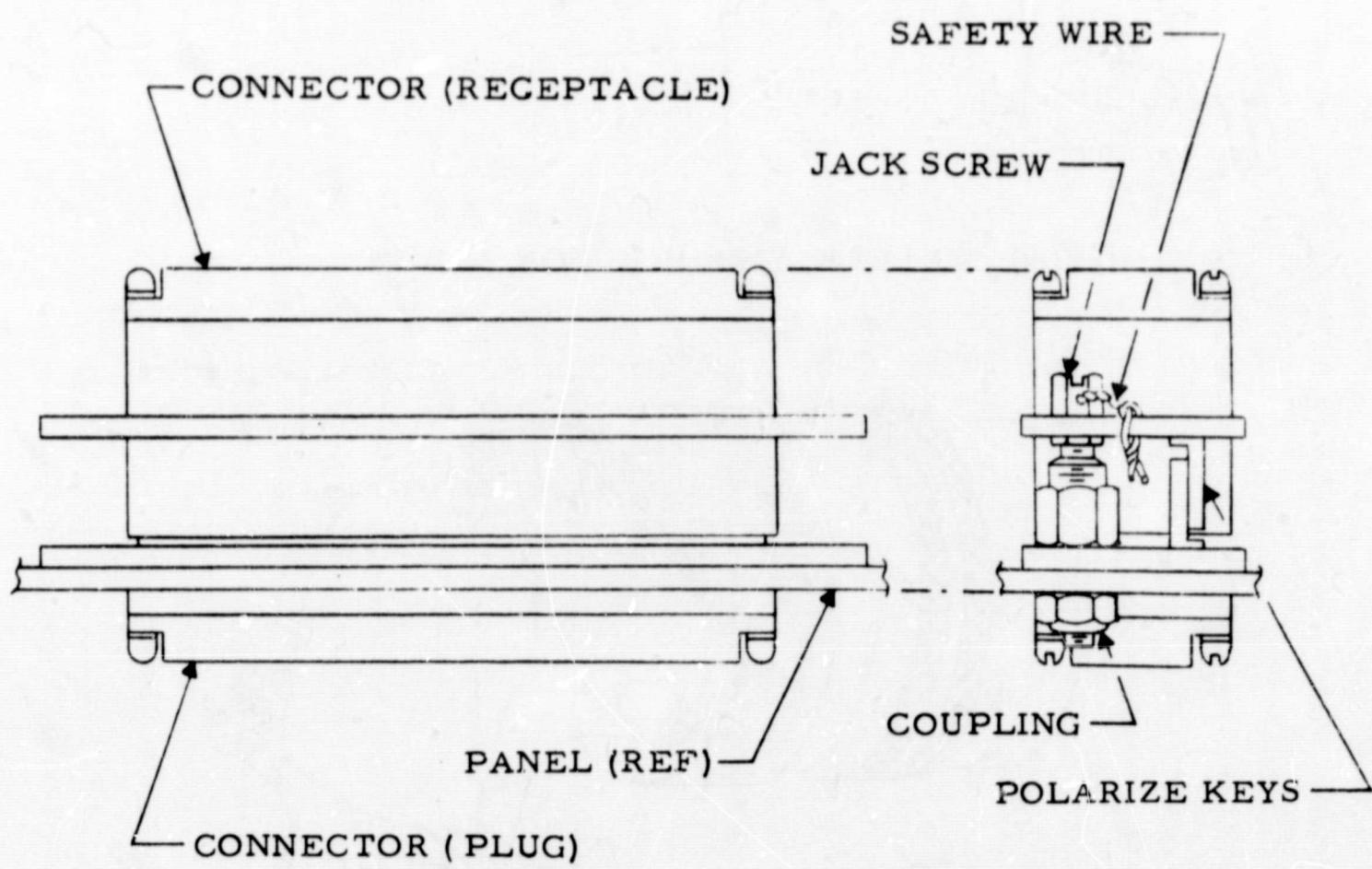


FIGURE 18-9 RECTANGULAR CONNECTOR MATED

## SECTION 19

### TEST

#### 19.1 GENERAL

This section establishes the requirements for performing continuity, insulation resistance, and dielectric withstanding voltage tests of electrical harness assemblies. Acceptable harness continuity will be assured by determining that the cable conductor resistance is less than the specified maximum value. Acceptable insulation resistance will be assured by determining that the wire insulation resistance is higher than the specified minimum value. Performance of the dielectric withstanding voltage test will assure that the wire and cable insulation material and connector terminations have not been degraded during previous fabrication and handling operations. The continuity and insulation resistance tests may be performed, at the option of the harness fabricator, whenever it is deemed prudent to assure the status of electrical integrity prior to performing a manufacturing process, such as potting of connectors. The performance of these interim tests does not preclude performance of the mandatory final post-fabrication tests.

#### 19.2 SAFETY REQUIREMENTS

Care shall be exercised during dielectric withstanding voltage and insulation resistance tests, which are performed at voltages hazardous to operating personnel. All test equipment used during the tests shall be thoroughly grounded and shall incorporate protective devices to guard personnel against electric shock. Personnel shall be kept away from output terminals of any test equipment, test cables, and harnesses while the tests are being performed.

#### 19.3 TEST PREPARATION REQUIREMENTS

Preliminary preparation prior to electrical tests shall consist of verification that the harness assembly has satisfactorily completed the scheduled fabrication processes and is ready for test. Verify that all required test equipment is ready and is of the proper type, and has current

### 19.3 TEST PREPARATION REQUIREMENTS (Continued)

calibration certification. All personnel involved in the testing of harness assemblies, shall be properly instructed and adequately trained to operate the test equipment per the test procedure.

#### 19.3.1 SPECIAL PRECAUTIONS

Receptacles shall be mated to plug under test prior to attaching test leads. The type and size of mating test plug or receptacle must match the connector undergoing test. Prior to connector mating and following connector demating, verify that each connector has no bent pins or sockets, punctured inserts, and/or any other visible damage. Mating or demating of individual connectors must be done carefully to prevent damage to the connector shell and the connector contacts. A connector shall never be demated while a test voltage is being applied to the connector. Always verify that connector protective covers are installed or replaced on unmated connectors following testing.

**WARNING:** Under no circumstances shall wire or cable insulation be probed with test lead probes or clips nor shall probes or clips be permitted to touch or be attached to the connector contacts.

#### 19.3.2 PRE-POTTING PRE-TEST VERIFICATION

Prior to pre-potting electrical test, verify that all connectors are free of contamination, loose wire strands, loose solder, etc. Examine connector grommets for damage, recessed or bent pins, and other damage that may occur during handling and previous processes.

#### 19.3.3 HARNESS POST-FABRICATION PRE-TEST VERIFICATION

Prior to the post-fabrication test which follows completion of harness fabrication, assure that the completed harness assembly has complied with all applicable drawings, design criteria, fabrication requirements, and workmanship requirements, e.g., overall dimensions, bend radii at breakouts, harness identification, and handling damage (connector bent pins, damaged inserts, and damaged, missing, or improper "o" rings).

#### 19.3.4 HARNESS POST-INSTALLATION PRE-TEST VERIFICATION

Prior to the post-installation tests verify that all connectors remain demated and that the harness assembly has been installed correctly and has the correct bend radii, protection from chafing, proper clamping and marking. Check all connectors for obvious handling damage, e.g., bent pins, damaged inserts, and damaged, missing, or improper "o" rings prior to test.

#### 19.4 HARNESS ASSEMBLY CONTINUITY TEST REQUIREMENTS

Each harness assembly shall be tested for point to point electrical continuity in accordance with the applicable wiring diagrams or engineering documentation. The circuit resistance shall be a maximum allowable of two (2) ohms, and the test voltage shall not exceed 50 Vdc. Any circuit having a resistance value greater than two (2) ohms, excluding the resistance in the test equipment and adapter cables, will be considered unacceptable. Continuity test of insulated shields shall not be made unless the shielding is terminated at a contact in the connector or at the connector shell.

#### 19.5 HARNESS ASSEMBLY DIELECTRIC WITHSTANDING VOLTAGE (DWV) REQUIREMENTS

Whenever the dielectric withstanding voltage test is performed it shall be performed after the continuity test and be followed by the insulation resistance test. Since this DWV test is generally recognized as potentially accumulatively destructive to insulation, the test is performed once on the harness assembly, at the completion of harness fabrication. The harness assembly shall be capable of withstanding the application of 1000 volts (minimum) RMS, 60 CPS, or 1500 volts dc power for one minute maximum. Leakage current shall not exceed 0.5 milliamperes. An appropriate current measuring device, capable of indicating leakage current of 0.5 milliamperes or greater, and breakdown due to a sustained arc, shall be used during performance of this test. The voltage shall be applied at a rate of 500 volts per second, and shall be maintained for a maximum of one minute between:

- a. Each conductor and all other connector contact terminated conductors in the same harness assembly.
- b. Each conductor and each connector shell.
- c. Each conductor and each shield that is accessible at a connector contact or shell, or at a junction device.

## 19.5 HARNESS ASSEMBLY DIELECTRIC WITHSTANDING VOLTAGE (DWV) REQUIREMENTS (Continued)

- d. Each spare connector contact and all other contacts (wired or spare) and connector shell.

The test voltage shall be maintained for sufficient time, not exceeding one minute, to assure that the leakage current has reached a steady state condition. Test methods shall comply with Method 301 of MIL-STD-202.

## 19.6 HARNESS ASSEMBLY INSULATION RESISTANCE TEST REQUIREMENTS

A test potential of 500 volts dc, plus or minus 25 volts dc, shall be applied for a minimum dwell time of 60 seconds. The measured insulation resistance shall be greater than 100 megohms.

### 19.6.1 POST-FABRICATION TEST

Harness assembly insulation resistance shall be measured between:

- a. Each conductor and all other connector contact terminated conductors in the same harness assembly.
- b. Each conductor and each connector shell.
- c. Each conductor and each shield that is accessible at a connector contact or shell, or at a junction device.
- d. Each spare connector contact and all other contacts (wired or spare) and connector shell.

Insulated shields shall not be subjected to the insulation resistance test unless the shielding is terminated at a contact in a connector and/or junction device, or at the connector shell.

### 19.6.2 POST-INSTALLATION TEST

Harness assembly insulation resistance shall be measured between:

- a. Each conductor and all other connector contact terminated conductors in the same harness assembly.
- b. Each conductor and each connector shell.
- c. Each conductor and each shield that is accessible at a connector contact or shell, or at a junction device.
- d. Space vehicle/payload structure and each conductor, connector shell, and accessible shield.

Insulated shields shall not be subjected to the insulation resistance test unless the shielding is terminated at a contact in a connector and/or junction device, or at the connector shell.

## 19.7 TEST OPERATIONS

Test operations shall assure that the test requirements are fulfilled.

### 19.7.1 POST-FABRICATION TESTING TECHNIQUE

Automatic or manual test equipment may be employed for post-fabrication continuity, dielectric withstanding voltage, and insulation resistance testing. When more complex harness configurations are involved, such as a harness having more than a nominal number of connectors or having a design such that a master connector, or two, is not evident, the automatic test equipment is highly desirable. Test adapter harnesses connected to each connector or junction device of the harness under test, and terminated in the automatic test equipment, will allow total test of all the parameters stated above as test requirements. An automatic test program can be prepared as a universal program, with resulting test anomalies being judged as either prescribed design or nonconformances. Automatic equipment with a universal program affords a minimum test preparation and maximum repeatability. The test program may be further reduced during the dielectric withstanding voltage test and the insulation resistance test by "commoning" within the test equipment all conductors, connector shells, and shield terminations except that one conductor to be tested, and applying the test voltage between the conductor and the "commoned" conductors, etc. Evidenced anomalies will necessitate isolation of fault, while acceptable results simplify testing.

### 19.7.2 POST-INSTALLATION TESTING TECHNIQUE

Automatic or manual test equipment may also be employed for post-installation continuity and insulation resistance testing, as employed in the post-fabrication testing. However, due to the restrictions imposed by more complex space vehicle/payload structures, the accessibility of installed harness connectors, weight limitation, etc., automatic equipment may not be advised. Manual continuity testing is achieved by identifying the appropriate harness assembly connectors and measuring the resistance between the terminal ends of each conductor; long test leads are generally required and may require consideration in measuring circuit resistance. Manual insulation resistance testing is accomplished by identifying those harness assembly connectors in which one end of each harness conductor is terminated and applying the test voltage between each conductor terminated in the connector under test and

#### 19.7.2 POST-INSTALLATION TESTING TECHNIQUE (Continued)

the balance of the conductors, connector shells, shield terminations, and space vehicle/payload structure "commoned" via a test unit. To afford test between each conductor, etc., and all the connector shells during manual testing, all of the harness assembly connector shells not otherwise mounted to structure should be electrically connected to the space vehicle/payload structure, thus being "commoned" with the structure for test purposes. This electrical connection is best achieved, with minimum chance of connector damage, by employing a special single conductor jumper equipped with a clip at one end for attachment to a structure "ground" stud and a soft metal nominal size coiled spring, looped end-to-end, at the other end of the jumper. The looped spring can be slipped over the connector shell and retain its position of electrical contact with the connector shell.

SECTION 20  
POST INSTALLATION VERIFICATION

20.1 GENERAL

A post installation review shall be performed, upon the completion of installation of all harnesses and other manufacturing operations performed in the vicinity of harness installations. This review may be completed in appropriate increments if the installation areas are conveniently defined and completion of all manufacturing operations is so segmented. This section is provided as a basic guideline for performance of the post installation verification review and is intended for use in development of a complete and comprehensive installation review procedure.

20.2 PURPOSE

The objectives of the post installation verification review are (1) assessment of the installed wire harness routing, clamping, connector mating, and general lay to assure that the previously accepted installation of each harness has not been compromised by subsequent near-proximity manufacturing operations, harness installations, hardware modifications, etc; (2) general assessment of each installed harness, with emphasis on potentially susceptible areas, for damage or potential compromise of harness integrity; and (3) identification and formulation of design changes which (a) remove or reduce the potential of damage to networks harnesses during subsequent testing, handling, and mission performance, (b) provide improvement of crew and operator safety, and (c) improve the overall quality and reliability of the electrical networks.

20.3 POST INSTALLATION VERIFICATION

When it can be ascertained that all manufacturing operations have been completed within a distinct portion of an end assembly, a post installation verification review of all electrical networks harnesses comprising the completed area shall be performed. Special attention shall be given in

### 20.3 POST INSTALLATION VERIFICATION (Continued)

designating such areas to assure that such areas are not influenced by subsequent manufacturing operations, in adjacent areas, which would cause invalidation of an area verification review. Those harness installations which are enclosed in covered troughs or otherwise hidden from view by subsequent manufacturing operations shall be subjected to post installation verification review immediately prior to covering, thus precluding disassembly of hardware for performance of this review. However, special attention should be given to subsequent near-proximity manufacturing operations to assure that hidden damage is not incurred.

#### 20.3.1 FIRST ITEM REVIEW

The post installation verification review of the first production item shall be attended by the responsible design engineering group so that resolution of problem areas (potential or real) which can be corrected by design change can be expedited. Possible design considerations may include re-routing or combining harness segments, adding separators or clamps, revising harness lengths, etc., and shall be freely advanced to assure that the production item displays clean, orderly appearing harness installations of the highest quality. The participation of the design engineering group in this first quality review will also allow a cross fertilization of problems recognized by the participating quality assurance group.

#### 20.3.2 QUALITY VERIFICATION CRITERIA

The following checklist is provided as guidelines to inspection personnel. These guidelines are not to be construed as a complete list; inspecting personnel and persons compiling the inspection procedure are expected to employ their experience and knowledge of good harness installations practices and their initiative to insure the highest standard of quality:

- a. Harness fabrication quality has not been degraded by assembly/installation operations or other activities.
  1. Identification
  2. Corrosion
  3. Deformed or broken connectors

20.3.2 QUALITY VERIFICATION CRITERIA (Continued)

4. Fractured potting
5. Cleanliness (harnesses free from foreign matter)
6. Ruptured sleeving or sheathing
7. Disturbed shielding
- b. Harness installation has not been degraded.
  1. Support and clamping
  2. Protective wrapping, convolute, sheath, etc.
  3. Bend radius
  4. Slack
  5. Correct clamp (cushion not damaged)
  6. Capping and stowage
  7. Lacing and tying
  8. Grounding/bonding
  9. Spacing of harnesses
- c. Connector mating has been properly performed or connectors stowed.
  1. All harness connectors have been properly mated or stowed.
  2. Torquing has been accomplished, as specified.
  3. Safety wires are as prescribed, none broken, and no sharp strands.
  4. Quality seals are in place and have not been broken.

TECHNICAL MEMORANDUM TM X-64685

APPROVAL

MANUFACTURE AND QUALITY CONTROL OF  
INTERCONNECTING WIRE HARNESSES

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

*John M. Knadler, III*

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